

• REHABILITATION • TRAUMA • DIABETES • BIOMECHANICS • SPORTS MEDICINE

# ler

**LOWER EXTREMITY REVIEW**

November 15 / volume 7 / number 11

## BATTLES OF ACHILLES II:

*How the debate is informing  
clinical practice*

### PATIENT PERSPECTIVE

*SURGEON FINDS HIMSELF  
ON OTHER END OF SCALPEL*

### FOOT CARE

*EQUINUS: ITS SURPRISING  
ROLE IN MANY PATHOLOGIES*

### SPORTS MEDICINE

*QUADRICEPS SYMMETRY  
AFTER ACL RECONSTRUCTION*

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## November 2015

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By Cary Groner

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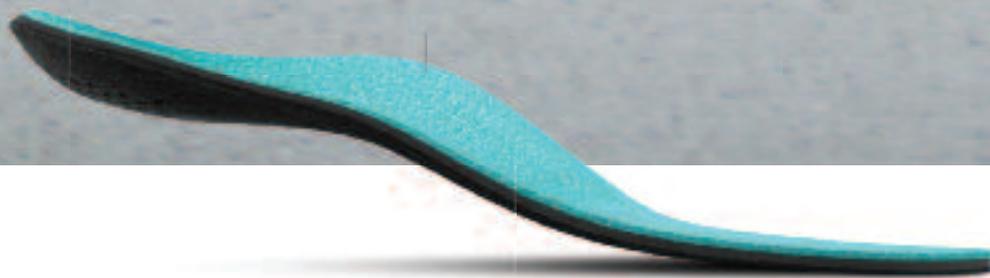
By Emily Delzell



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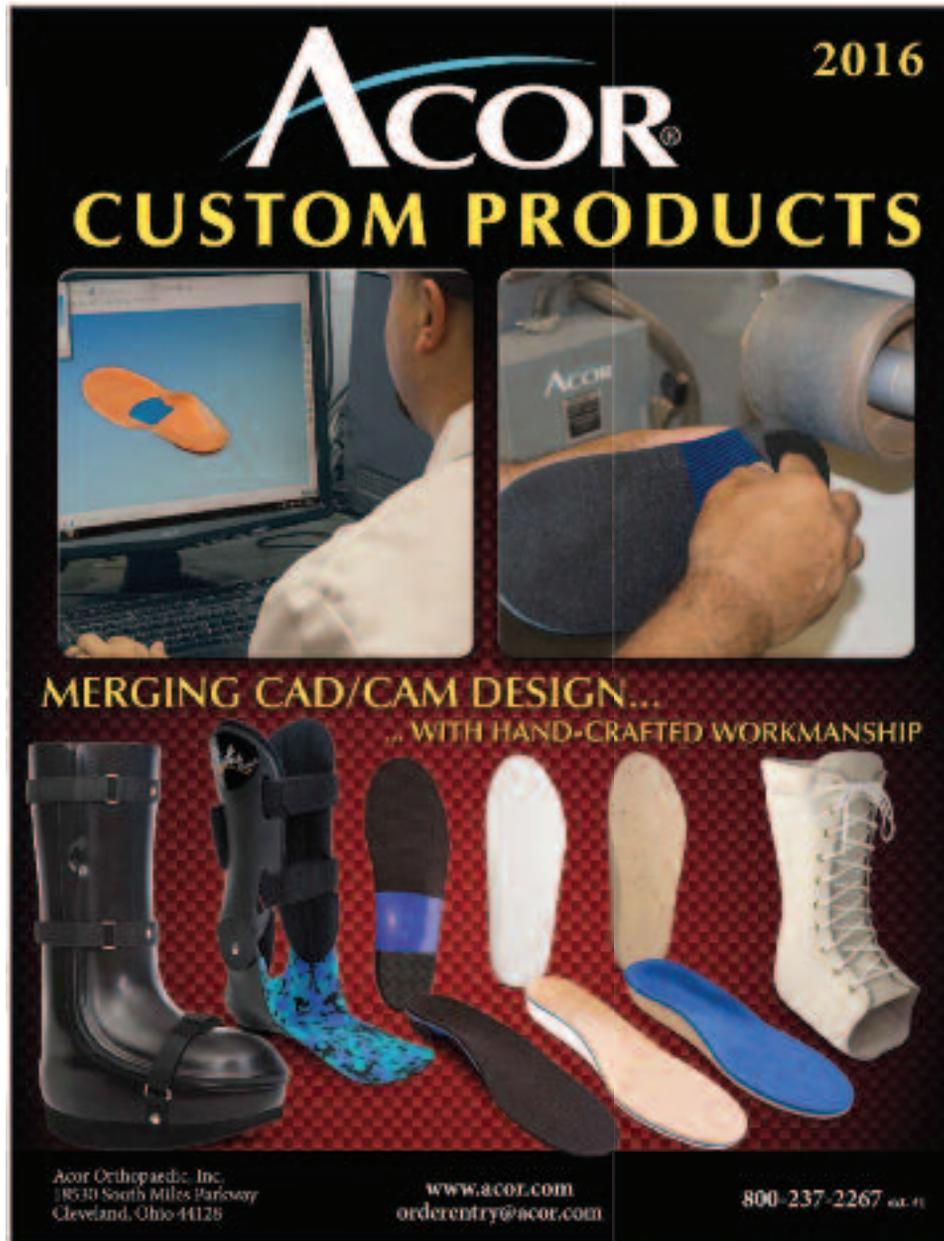
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Despite evidence of significant lower extremity injury risks associated with ice hockey, even at youth levels, preventing those types of injuries has never been a priority in that sport. But that may be starting to change.

According to a recent report from CBS Sports, five members of the Dallas

Stars professional hockey team—including Jamie Benn, the league’s leading scorer last season—have undergone surgery for femoroacetabular impingement (FAI) in the last year. Rather than let players continue to play through the pain and functional limitations of FAI, which historically has been the way many injuries are managed in hockey, team medical personnel have decided to take a more aggressive approach in hopes of preventing worse disability—and more lost ice time—in the longer term.

The clinical merits of such an approach are probably debatable. But what’s clear is that the more professional hockey players who undergo surgery for FAI, the more coaches and parents of youth hockey players will realize that the risk of FAI is something they should be taking seriously.

Marc Philippon, MD, hip surgeon to the stars, and colleagues at the Steadman Philippon Research Institute in Vail, CO, documented this risk in a 2013 study that found 75% of youth hockey players had alpha angles associated with cam-type FAI, compared with 42% of similarly aged skiers. More recently, an October 2015 study from Switzerland found that, on magnetic resonance imaging, 68% of male youth ice hockey players had FAI-related bony deformities.

When presenting the preliminary data from his study in Monaco at the 2011 World Congress on Prevention of Injury and Illness in

## out on a limb: Hockey gets hip to FAI

Sport (see “Screening has benefit, but Philippon calls for more action to save hips in hockey,” May 2011, page 25), Philippon called for youth ice hockey leagues to manage players’ ice time—in much the same way as youth baseball leagues manage players’ pitch counts—to help reduce the risk of FAI. But that hasn’t happened.

Like baseball, ice hockey is a sport in which many kids are encouraged to specialize at a very early age, a factor that itself dramatically increases the risk of overuse injury in those who continue to play through high school. To be fair, ice hockey is a more physical sport than baseball, even at youth levels, and most youth hockey leagues are rightly focusing their prevention efforts on concussion and other traumatic injuries.

But baseball is also a much higher-profile sport than ice hockey, at least in the US. Pitch counts for youth baseball players weren’t implemented just because sports medicine experts said it was a good idea; they were implemented because an increase in the number of professional players undergoing Tommy John surgery brought the problematic practice of overusing young arms into the public spotlight.

**The more professional hockey players who undergo surgery for FAI, the more youth hockey will start taking the risks seriously.**

If more hockey teams start focusing on FAI at the professional level, it will go a long way toward increasing awareness at lower skill levels, where intervention can really make a difference. That’s something players, parents, coaches, and fans at any level should be able to root for.

Jordana Bieze Foster, *Editor*



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By Katie Bell and Jordana Bieze Foster

## Fusion and low vitamin D Two thirds of patients have deficiency

Vitamin D deficiency is prevalent in patients in the northern US undergoing mid-foot, hindfoot, and ankle arthrodesis, even in those without predisposing risk factors, according to a recent study from Vermont that may have implications for lower extremity surgery.

Because the study was retrospective, the findings do not reveal the extent to which low vitamin D contributed to the need for arthrodesis, said first author James Michelson, MD, a professor of orthopedics in the Department of Orthopaedics and Rehabilitation at the University of Vermont College of Medicine in Burlington. However, the authors concluded that routine testing for vitamin D deficiency and high-dose vitamin D therapy when appropriate should be considered for all patients slated for such procedures.

The study included 81 nonselected patients undergoing a major ankle, hindfoot, or midfoot arthrodesis between May 2012 and

## Intrinsic exercises may help runners safely switch to minimalist footwear

The development of bone marrow edema after transitioning from traditional running shoes to minimalist footwear is associated with small intrinsic foot muscle size, according to research from Brigham Young University in Provo, UT.

The findings, published in late October by the *International Journal of Sports Medicine*, suggest that runners with small intrinsic foot muscles may benefit from strengthening exercises prior to attempting the transition to minimalist running.

Investigators randomized 37 habitually shod runners to 10 weeks of running in minimalist footwear or their own shoes, and performed magnetic resonance imaging at baseline and after the

intervention to detect bone marrow edema and assess intrinsic foot muscle size.

Eight of the runners in the minimalist group had developed bone marrow edema at 10 weeks, as well as one in the control group. Those who developed bone marrow edema had significantly smaller intrinsic foot muscles than those who did not.

In addition, running in minimalist footwear was associated with a 10.6% increase in abductor hallucis cross-sectional area, a statistically significant change.  —JBF

Source:

Johnson AW, Myrer JW, Mitchell UH, et al. The effects of a transition to minimalist shoe running on intrinsic foot muscle size. *Int J Sports Med* 2015 Oct 28. *IEpub ahead of print*



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February 2014 in Burlington, which has a latitude of 44.5° north. The authors noted that vitamin D deficiency is highly prevalent in latitudes above 30°.

Clinical data, including comorbidities, demographics, and laboratory values, were obtained from an electronic medical record system that incorporated all patient care. For the study, vitamin D levels above 30 ng/mL were considered normal, based on the Endocrine Society's Vitamin D Task Force Committee recommendations.

Fifty-four patients (67%) had vitamin D deficiency, with a mean serum vitamin D of 27 ng/mL. Although patients with vitamin D

*Continued on page 14*

## Half shoe outperforms double rocker for offloading, but also impairs gait

A half shoe offloads the forefoot more effectively than a double-rocker full-outsole shoe with an offloading insole, but the half shoe also is more likely to alter gait, according to research from Bologna, Italy.

Investigators from the Istituto Ortopedico Rizzoli assessed 10 healthy women as they walked wearing a control shoe on the left foot and one of three types of footwear on the right foot: a control shoe, a half shoe, and a double-rocker, full-outsole shoe with an insole designed to reduce forefoot loading. The anterior aspect of the insole was thicker than the posterior aspect, to maintain the foot in slight dorsiflexion.

Maximum force at the fore-

foot as a percentage of body weight was significantly lower for the half-shoe condition than the other two conditions, indicating greater offloading. The same variable did not differ significantly between the double-rocker shoe and the control shoe. However, the half shoe was also associated with slower walking speed, shorter stride length, and less ground reaction force in late stance compared with the control condition.

The findings were published in October by the *Journal of Foot and Ankle Research*.  —JBF

Source:

Caravaggi P, Giangrande A, Berti L, et al. Pedobarographic and kinematic analysis in the functional evaluation of two postoperative forefoot offloading shoes. *J Foot Ankle Res* 2015;8:59.

# in the moment: foot care

Continued from page 13

deficiency were significantly younger than those with normal levels, those with low vitamin D were more likely to have a Charlson comorbidity index of three or more (indicating multiple comorbidities). The study also found patients with diabetes were at increased risk for low vitamin D, but several other variables typically thought to be predisposing risk factors—gender, obesity, and seasonality—were not significantly associated with vitamin D levels.

All patients with low vitamin D levels were treated with 50,000 IU of vitamin D2 three times per week for two months. Additionally, all patients were given 2000 IU of vitamin D3 daily, along with twice-daily calcium carbonate 750 mg. One month after completion of the vitamin D supplementation, a

repeat vitamin D test was performed in 16 patients. Only nine had corrected to normal values, which Michelson said is not an unusual finding, given that many patients, especially those with diabetes, are relatively resistant to vitamin D supplementation.

The surgeries were not delayed in patients with low vitamin D levels, nor was surgical technique altered for such cases. Healing rates did not differ significantly between patients with low vitamin D and those with normal levels, but Michelson noted that the sample was too small to draw any conclusions from that finding. The study was published by *Foot & Ankle International* in October.

Contrary to the Vermont study findings, Karl Dunn, DPM, AACFAS, a fellow at the Pennsylvania Intensive Lower Extremity

Fellowship at Premier Orthopaedics and Sports Medicine in Malvern, noted that vitamin D insufficiency has previously been associated with increased age, obesity, female gender, and seasonality, among other factors.

In a study epublished in September, Dunn and colleagues examined the serum concentrations of vitamin D in 124 patients with confirmed stress fractures, and found an association between low vitamin D and stress fractures.

Those findings suggest hypovitaminosis D can lead to osteoporosis, osteomalacia, decreased bone mineral density, and, subsequently, the risk of acute fracture, he said.

“Currently, we know in the context of vitamin D deficiency, bone turnover and osseous healing can be negatively impacted,”

Dunn said. “Intuitively, I believe some at-risk fractures, osteotomies or arthrodesis type procedures could have a delayed or nonunion as a result of a vitamin D deficiency,” he noted, adding that future research examining larger populations undergoing these types of surgeries will further explore these speculations, and hopefully provide an accurate threshold as to what vitamin D level will yield normal bone healing and metabolism and avoid potential complications.  —KB

Sources:

Michelson JD, Charlson MD. Vitamin D status in an elective orthopedic surgical population. *Foot Ankle Int* 2015 Oct 1. *IEpub ahead of print*

Miller JR, Dunn KW, Ciliberti LJ Jr, et al. Association of vitamin D with stress fractures: A retrospective cohort study. *J Foot Ankle Surg* 2015 Sep 23. *IEpub ahead of print*



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By Lori Roniger and Jordana Bieze Foster

## On the move

### Gait training improves limited mobility

Gait training is effective for improving limited mobility in patients with knee osteoarthritis (OA), according to a recent study, but the immediate benefit is not sustained after training has stopped.

In the study, researchers randomized 56 men and women aged 60 years and older with symptomatic knee OA and mobility limitations to 12 weeks of either usual care or a gait training intervention. The intervention group received twice weekly 45-minute gait training sessions, supervised by a physical therapist, plus a therapist-designed individualized home exercise program to increase range of motion, strength, or both.

At three months, the gait training group experienced significantly greater improvement in Late Life Function and Disability Index Basic Lower Limb Function score and Knee Injury and Osteoarthritis Outcome Score symptoms compared with the control group, but these differences were not maintained at six and 12 months. The findings were published in October by the *American Journal of Physical Medicine and Rehabilitation*.

## Cartilage thickness study suggests role of kinetics changes with OA severity

Although knee adduction moment (KAM) plays a significant role in patients with severe knee osteoarthritis (OA), knee flexion moment (KFM) may be more important early in the disease process, according to research from Stanford University in California.

In 70 patients with medial compartment knee OA, investigators determined knee moments using gait analysis and knee cartilage thickness using magnetic resonance imaging. They then performed multiple linear regression analyses to identify associations among knee moments, cartilage thickness, and knee OA severity.

Medial cartilage thickness and medial-to-lateral cartilage thickness ratio were significantly

associated with KAM for specific knee regions, but only in patients with severe knee OA. KFM was significantly associated with cartilage thickness for specific tibial plateau regions, but only in patients with less severe disease.

The findings, published in October by the *Journal of Biomechanics*, suggest that KFM may be important early in the development of knee OA, but that KAM plays a greater role as pain increases. The authors recommended that both kinetic variables be considered in patients with knee OA.  —JBF

Source: Erhart-Hledik JC, Favre J, Andriacchi TP. New insight in the relationship between regional patterns of knee cartilage thickness, osteoarthritis disease severity, and gait mechanics. *J Biomech* 2015 Oct 8. *IEpub ahead of print*



Participant-specific biofeedback during instrumented treadmill gait training. Examples of real-time biofeedback provided during gait training for correction of kinematic patterns. (Reprinted with permission from Segal NA, Glass NA, Teran-Yengle P, et al. Intensive gait training for older adults with symptomatic knee osteoarthritis. *Am J Phys Med Rehabil* 2015;94[10 Suppl 1]:848-858.)

The authors recruited knee OA patients with moderate to severe mobility problems because they have the greatest need for mobility improvements, explained lead author Neil A. Segal, MD, MS, professor, faculty physiatrist, director of clinical research, and medical director of musculoskeletal rehabilitation in the Department

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## Patient-reported function, kinematics predict response to hip strengthening

Patient-reported function and lower extremity kinematics can predict response to a hip strengthening intervention in patients with knee osteoarthritis (OA), according to research from the University of Calgary in Alberta, Canada.

Investigators recruited 39 patients with mild to moderate knee OA to complete a six-week hip strengthening intervention, with one supervised session per week plus home exercises an average of 5.5 days per week. The researchers then grouped the patients according to their improvement in symptoms and function after six weeks, based on effect size, and looked for associations between patients' baseline variables and their response to the intervention.

Patient-reported function in

daily living and frontal plane hip kinematics during loading response best differentiated the 11 high responders from the 14 low responders and 14 nonresponders. A combination of hip, knee, and ankle kinematics differentiated low responders from nonresponders.

The combination of predictive factors was able to successfully classify patient response to the hip strengthening intervention with an overall accuracy of 85.4%. The findings were published in October by *PLoS One*.  —JBF

Source: Kobsar D, Osis ST, Hettinga BA, Ferber R. Gait biomechanics and patient-reported function as predictors of response to a hip strengthening exercise intervention in patients with knee osteoarthritis. *PLoS One* 2015;10(10): e0139923.

# in the moment: osteoarthritis

Continued from page 15

of Rehabilitation Medicine at the University of Kansas Medical Center in Kansas City. However, the patients' limitations may have been too severe for them to significantly benefit from the intervention, he said.

Gait training was performed on an instrumented treadmill; force plate data and computerized motion analysis were used to generate real-time visual feedback on a computer screen. As they walked on the treadmill, patients were shown either a skeletal image of their alignment or a graph of specific kinematic patterns with a shaded area representing a target range. The patients were then directed to modify their gait in ways that would correct the feedback images.

During the training, the therapist and patient monitored the reduction of the external

knee adduction moment and pelvic control, while the therapist confirmed that moments at other joints were not negatively affected.

Segal said that external knee adduction moment and hip extensor range of motion improved at three months in the gait training group, although the published article did not include these data.

He also said the patients appreciated the gait training program.

"Not only did they seem to like it, ninety percent were compliant six to nine months after they completed it," he said.

The patients were encouraged through scripted motivational telephone interviews at four, five, eight, and 10 months to continue the program on their own.

"I think booster sessions

could be helpful," Segal said, suggesting that a gait training session every six to 12 weeks after the 12-week program might help sustain the initial gains.

He noted the study was resource intensive, and that it would be helpful to sort out which aspects of the gait training intervention could be removed while maintaining its positive effect.

Michael A. Hunt, PT, PhD, associate professor in the Department of Physical Therapy at the University of British Columbia in Vancouver, said his strategy has been to take a patient's normal alignment and change an aspect of it, such as foot or trunk position, to offload the knee.

"This is in contrast to other pathologies where the aim is to bring them back to neutral,"

Hunt said. "The key difference is that neutral movement is likely related to efficiency and function, while what we are doing is for the sole purpose of redistributing the loads within the knee joint—albeit likely at some cost of efficiency and/or stability. For knee OA, the load distribution is key."

While a multifaceted approach including gait retraining and increasing strength and range of motion may be helpful for knee OA patients, the effects of each of these areas needs to be tested in isolation, Hunt concurred.

"I think it's still a bit early to throw all of our eggs in the gait retraining basket," he said.  —LR

Source:

Segal NA, Glass NA, Teran-Yengle P, et al. Intensive gait training for older adults with symptomatic knee osteoarthritis. *Am J Phys Med Rehabil* 2015;94(10 Suppl 1):848-858.

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The Silver Finger/Toe dressing was easily applied.

**Patient 2** was a 71-year-old diabetic male with a history of poor vascular perfusion, below-the-knee amputation of the right leg, and venous stasis ulcers. The hook-and-loop fastener of a post-operative shoe created a friction wound on the top of the toe on his remaining foot. The periwound skin became edematous and macerated. Using the PolyMem Finger/Toe dressing, he was able to do his own dressing changes and the periwound maceration, swelling and weeping decreased. The wound, which originally measured 0.5 cm x 0.7 cm x 0.1 cm, was closed in 14 days. Only two PolyMem dressings were used to close this wound.

**Patient 3** was a 56-year-old paraplegic female whose shoe came off when her foot fell from the wheelchair footrest, resulting in an avulsion of the second toenail of the left foot. The periwound skin became slightly erythemic and edematous. Her dressing changes were performed by home health and the wound closed in only three days.

**Patient 4** was a 56-year-old male who suffered an amputation at the proximal joint of the first finger of his right hand while operating a hydraulic log-splitter. A surgical flap was attempted, but it was unsuccessful. The periwound skin was swollen, macerated and warm to the touch. He received whirlpool baths to the wound twice weekly by physical therapy. He changed his own dressings when required and when no whirlpool treatments were scheduled. The macerated periwound skin resulting from the whirlpools was managed with a barrier cream. The pain during the whirlpool treatments was managed with oral analgesia. All these wounds healed rapidly using PolyMem Finger/Toe dressings.

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After application of PolyMem dressings, all these patients experienced significant swelling reduction in the affected digits and saw rapid resolution of any previously present periwound skin complications. Nurses, patients and caregivers found the dressings easy and convenient to use. Finger/Toe dressings were shown to be cost effective when compared to other approaches as the number of dressings used was significantly decreased, the time needed for dressing changes was minimal and the home health nurses made fewer visits. PolyMem dressings provided optimal healing environments, which resulted in rapid wound resolutions.



The entire dressing was applied to cover the the knuckle as well as the wound in order to help reduce the swelling faster.

### Reference:

1. Harrison J. Successful Healing of Digit Wounds with One Dressing. Poster 6130. Wound Ostomy and Continence Nurses Association (WOCN). June 9-13, 2012. Charlotte, NC, USA.



# BATTLES OF ACHILLES II:

*How the debate is informing  
clinical practice*

Four years later, the ongoing discussion of the relative merits of surgical and nonsurgical management of Achilles tendon rupture is starting to affect practice patterns – even in the US.

By Cary Groner

When *LER* first reported on research concluding that nonsurgical and surgical treatment of Achilles tendon rupture yielded similar outcomes,<sup>1</sup> the issue had become so contentious that a shouting match erupted at the 2011 meeting of the American Academy of Orthopaedic Surgeons (AAOS). Now, four years later, clinicians on both sides still defend their positions even as they've begun to inch toward common ground.

The goal of Achilles rupture management, regardless of approach, is homogenous healing, regeneration, and functional restoration.<sup>2</sup> To achieve this, clinicians must avoid complications such as rerupture and infection. Unfortunately, these aims can be mutually contradictory; studies suggest that surgery is associated with lower rerupture rates than nonoperative management but a higher risk of infection. Nonsurgical approaches pose their own challenges, including patient compliance with rehabilitation protocols that can be frustrating and prolonged.<sup>2</sup>

## Incidence and demographics

Study results have begun to affect practice patterns regardless, particularly in Europe. For example, a recent study in the *American Journal of Sports Medicine (AJSM)* reported that in Sweden between 2001 and 2012, surgical treatment declined from 43% to 28% of cases in men, and from 34% to 22% in women.<sup>3</sup>

Varying increases in incidence of Achilles rupture have been observed worldwide. Over 33 years, incidence in one Finnish city rose dramatically from 2.1 to 21.5 per 100,000 person-years in all age groups.<sup>4</sup> By contrast, a recent study in Denmark found that, though there was just a slight incidence increase from 1994 to 2013, the most significant rise occurred in those older than 50 years; in those aged 31 to 50 years, there was no significant change, and in those aged 18 to 30 years, there was a decrease in ruptures.<sup>5</sup>

"I believe the incidence increase is due to older people remaining active in sports," said one of the study's authors, Kristoffer Barfod, MD, PhD, who practices at Hvidovre University Hospital in Copenhagen.

The bump in cases isn't just a European phenomenon.

"We're seeing older people with very high activity levels, and I think that's one reason for the increased rates," agreed Lowell Weil Jr, DPM, who is chief executive officer of Weil Foot & Ankle USA, in Des Plaines, IL. "As we get older we become less flexible, and injuries that might have been a pull or a partial tear in a younger person become complete ruptures because the tissue isn't as tensile."

David Richardson, MD, an orthopedist at the University of Tennessee-Campbell Clinic in Memphis, said the Achilles ruptures he sees are often in patients involved in high-intensity sports protocols or exercise regimens.

"Instead of walking for thirty minutes, they're doing intense routines for six minutes, and I think that overloads the tendon," Richardson said.

According to Jonathan Chang, MD, a clinical associate professor of orthopedics at the University of Southern California in Los Angeles, increasing incidence in the US might be attributable to the opposite of increased activity in older people—that is, sedentary behavior and the obesity that comes with it.

"The more weight you carry, the more stress you put on the tendon," Chang said.

The trend may apply to the chronic problems that often precede acute tears, as well.

"I'm seeing a huge increase in Achilles tendinitis," said Stuart Miller, MD, who practices in the Department of Orthopedic Surgery at Union Memorial Hospital in Baltimore, MD. "Most Achilles ruptures arise out of chronic conditions. Some of these people just exercise once or twice a week—say, go out and play basketball on the weekend. Their gastrocnemius muscles just get tighter and tighter, and pull too hard on the Achilles."



## To cut or not to cut

The uptick in cases, and the older patients sometimes affected, may influence clinicians' decisions about approach to treatment, but not always in predictable ways. Invariably, the discussion circles back to whether surgery is the best option for any given patient.

The Canadian meta-analysis that provoked the AAOS skirmish found if patients had functional rehab including early range-of-motion (ROM) exercises, rerupture rates were equal for surgical and nonsurgical patients.<sup>6</sup> Without early ROM therapy, surgery had an 8.8% lower rerupture risk but a 15.8% higher risk of other complications, both statistically significant differences. Surgical patients returned to work significantly (19 days) sooner, but the treatments were equivalent in terms of strength and functional outcomes. (The authors could not be reached for comment.) That study followed a 2010 study, also from Canada, that also found outcomes to be similar between groups and recommended functional rehab and nonsurgical treatment.<sup>7</sup>

But not all research has reached similar conclusions. For example, a 2008 paper compared risk of complication other than rerupture and reported a rate of 21% for surgical treatment versus 36% for nonsurgical therapy (many of the complications in the nonoperative group were minor skin problems related to brace wear). As in most studies, moreover, return to work was significantly faster with surgery—59 days versus 108 days for those treated nonoperatively.<sup>8</sup>

Another issue is that, although research consistently finds higher rerupture rates in nonsurgically treated patients than their surgical counterparts, the between-group differences are often not statistically significant. Even so, the papers usually shed light on related matters.

For example, in a 2010 article in *AJSM*,<sup>9</sup> Scandinavian researchers reported rerupture rates of 4% in the surgical group and 12% in the nonsurgical group—not a statistically significant difference, but one the authors said might be considered clinically important. Although muscle function was better in the surgical patients at six months, the two groups were about the same by 12 months.

In a 2011 paper in the *Journal of Bone and Joint Surgery*,<sup>10</sup> researchers reported rerupture in 5% of operative patients and in 10% of those in the nonoperative group, a nonsignificant difference. The between-limb difference in plantar flexion peak torque was significantly smaller in those treated surgically, as well, though the disparity disappeared a year out from treatment.

The authors of a 2012 systematic review reported that surgical repair was associated with a 3.6% rerupture rate, versus 8.8% for nonsurgical treatment—a statistically significant difference in this

case.<sup>11</sup> Surgically treated patients had a higher incidence of deep infections, scarring, and sural nerve disturbances, however.

Then, in 2013, another Scandinavian study reported that in 100 patients, there were no reruptures in the surgical group (n = 49) but five in the nonsurgical group, a finding that trended toward statistical significance. Operative treatment was not deemed superior in other variables, however, including physical function and quality of life.<sup>12</sup>

Finally, a 2014 meta-analysis found that rerupture rates were 3.6% and 8.8% for patients treated with open surgery and nonsurgically (odds ratio .425 favoring surgery), respectively, though other complications such as infections and scarring were higher in surgical patients.<sup>13</sup>

## Clinical experience and technique

US surgeons have questioned some of these findings based on their own experience.

“The Canadian study [by Soroceanu<sup>6</sup>] showed a fairly high incidence of skin problems with an open Achilles tendon repair, something like fifteen percent,” Stuart Miller said. “I’d never seen anything like that, so I went through our records of more than two hundred acute Achilles ruptures over twenty years, and found a two or three percent incidence of skin problems.”

Miller, who was the moderator at the 2011 AAOS meeting when tempers flared, acknowledges a trend toward nonoperative treatment, but still has qualms.

“I think it slows down recovery,” he said. “My athletes and very active patients definitely get open repair. The patient is just more likely to stretch out a tendon that’s healed by scar formation and fibrosis and reformation. For the first year or two, that’s not going to be as strong as a thick suture holding everything together.”

Miller emphasized, moreover, that in his 21 years of practice only one of his patients has had a postsurgical infection, so he remains skeptical about some of the numbers reported in the literature. He’s not alone.

“Mark Twain said there are lies, damned lies, and statistics,” Richardson said. “Sometimes it’s hard to get numbers such as rerupture rates to reach statistical significance. That’s part of why some of us don’t abandon surgery—we see in our practices that patients get stronger faster that way. Operative risks are much lower than they used to be, too, because our approaches have improved.”

Chang concurred.

“Maybe it boils down to technique, but I’ve not had any problems with skin healing, and I’ve never had an infection,” he added. He continues to use an open approach with a Krakow suturing technique, which he feels offers the strongest fixation.

“In my practice I have a zero rate of rerupture,” he continued.

“That was one of my objections to the Scandinavian studies; they did a modified Kessler stitch, and you have to immobilize longer if you don’t trust your repair.”

Other surgeons have opted for less invasive approaches, often involving Achilles repair devices such as the Percutaneous Achilles Repair System (PARS). Lowell Weil uses PARS, as does Richardson.

“It allows me to put a suture inside the Achilles sheath and lock it,” Richardson said. “It’s a small, two-centimeter incision,

Some surgeons have found that a less-invasive approach, using Achilles repair devices such as the Percutaneous Achilles Repair System (PARS), helps to reduce complication rates. (Photo courtesy of David Richardson, MD).



and because of that there’s a very low complication rate.”

Stuart Miller prefers a core-weaving technique developed by his colleague, Greg Guyton, MD.

“It’s like a Krakow, but we do a cross stitch and bury the suture within the tendon most of the way, which theoretically lets the tendon glide more easily,” he said. “The incision heals side-to-side, which I think puts less strain on the tissues. It also lets me go up a little higher to get a good bite of tendon.”

## Patient profiles

All that said, clinicians told *LER* that they’re getting more comfortable with the idea of nonsurgical repair. Often the decision has to do with patient profile.

“People in sports medicine still have a bias that, for an elite athlete, a nonoperative treatment is not likely to be as good,” Chang said. “My patient population is tilted toward sports people, and they recognize that there is triple the risk of rerupture nonoperatively, so eighty percent say they want surgery.”

Chang added that he’s more open to nonoperative approaches than he used to be, however. Recently, in fact, he saw a patient with a chronic Achilles rupture who had never received any treatment at all.

“She came to see me two months after the injury, during which she’d basically gotten around by limping,” he said. “Even so, she’d

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reconnected her Achilles tendon without any immobilization. That's evidence that nonoperative approaches can work."

Chang also believes that patients older than 40 years, who are no longer elite athletes if they ever were, have a better chance of successful nonoperative treatment.

"I now see this more as a continuum," he said. "If you tear your Achilles when you're twenty, it's a much more devastating injury than if you're eighty because of your activity level. The average sedentary person will have a longer recovery, but by two months out they have enough connection that they can start to push off a little bit, and as long as they see ongoing improvement they do well."

Stuart Miller also said that he's more open to nonoperative repair. He's treated only four cases nonoperatively in the past 10 years, but that's twice the number he did in the decade before that.

"It depends on the individual," he explained. "One of those patients was an older doctor, in his late eighties, who'd read the research and decided he wanted a nonoperative approach. He did fine."

Miller believes that other arguments for a nonsurgical approach may include medical problems that may delay healing, including smoking and obesity.

Kristoffer Barfod, in Copenhagen, has a different take on patient profiling.

"I'm starting to think we should reverse the approach we've used before," he said. "My experience is that young, active people who can follow the nonoperative rehabilitation regimen heal very fast. On the other hand, some older people don't accept that they have an injury because there isn't much pain, so they keep walking and pull the tendon apart. If you operate, you secure the tendon and immobilize them so they can heal."

Lowell Weil agrees.

"I think there are advantages to surgery in older people, because they're the ones least able to handle long periods in a cast," he said. "If we can get them out of the immobilizing device faster by operating, then I go that route."

## All in the timing

Timing also affects treatment decisions, according to Barfod.

"If you wait too long, you miss the time period for doing a non-surgical treatment," he said. "You get an elongation of the tendon callus, then it shrinks. I believe it's crucial [in nonoperative treatment] to keep the foot in maximum plantar flexion for two weeks after injury in order to get a tendon callus of the correct length. If you start treatment too late you won't get that, and then you should probably choose a surgical approach. In our institution, if you come in later than four days, you get surgery."

Other surgeons have varying opinions about timing.

For David Richardson, if patients present with a chronic injury more than four weeks old, they're likely to get an open surgery rather than the PARS approach.

"The tendon edges tend to be retracted, scarred in, and not very mobile by then," he said. "It depends on what sort of deficit they have when they come in, however. If they're doing reasonably well, I might just recommend rehab alone."

Jonathan Chang will consider surgery up to three or four weeks out if the patient has kept weight off the injured limb, say, by using crutches.

"My general rule is that if it's more than three weeks, it's probably too late, because by then the ends of the tendon are like the ends of a mop," he said. "It's difficult to put it back together adequately. My

Though physicians report anecdotally that surgical cases proceed more quickly than nonsurgical cases, they allow that long-term outcomes may not differ significantly.

optimal time is generally seven to ten days after injury; I think most people prefer not to operate right afterward because you run into bleeding and you don't know the viability of the tissue yet."

Surgeons said they increasingly rely on ultrasound to assess tendon status. A 2011 article in *ISRN Orthopedics* provided a roadmap of seven classes of sonographic findings and the implications they held for treatment decisions,<sup>2</sup> though it isn't clear how widely they've caught on in the clinical community.

## Rehabilitation

Whether patients are treated surgically or nonsurgically, they still face rehabilitation, and, though physicians report anecdotally that surgical cases typically proceed more quickly, they also allow that long-term outcomes may show little difference.

"Early on, a surgical repair does better, but somewhere between eighteen and twenty-four months they equalize," Stuart Miller said.

Published studies usually address one of three conditions: post-surgical therapy; therapy after operative versus nonoperative treatment; or nonoperative rehabilitation alone.

In the first category, a 2015 randomized controlled trial (RCT) in Australia compared an accelerated mobilization rehab protocol with standard (immobilization) care.<sup>14</sup> Patients in the accelerated treatment group (n = 25) had less tendon lengthening and a quicker return to running than those in the standard group (n = 26), but similar results in the Achilles tendon Total Rupture Score (ATRS). The authors concluded that immobilization may prolong recovery.

A 2015 meta-analysis looked at 10 trials comprising 570 patients; some received early functional postoperative ankle motion and weightbearing (bracing group), whereas others had ankle immobilization with a nonweightbearing rigid cast (cast group).<sup>15</sup> In the bracing group, patients returned to preinjury activity levels faster and reported better satisfaction; there was no difference in complication rates.

In the second category—therapy after operative or nonoperative treatment—researchers in the Netherlands conducted a meta-analysis of rerupture rate and other variables in patients who began weightbearing within four weeks after surgery versus nonoperative care patients with similar weightbearing regimens.<sup>16</sup> Rerupture rates were 4% and 12% in the surgical and nonsurgical patients, respectively; a secondary analysis of patients who began weightbearing

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## Shear-wave elastography could help optimize Achilles rehab

Researchers at the University of Delaware in Newark are using a new ultrasound-based technique to better understand the effects of rehabilitation on the Achilles tendon, which could help optimize rehab protocols to improve long-term function.

A variety of problems complicate recovery from Achilles tendon ruptures, and patients often retain deficits in the damaged limb long after initial healing has occurred. One study reported that most patients still had symptoms, a reduced quality of life, and functional deficits 12 months after injury regardless of whether they received surgical or nonsurgical interventions.<sup>1</sup> Another found significant functional deficits on the injured side even after two years.<sup>2</sup>

One issue is that healed tendons often end up longer than they were originally, regardless of treatment. Tendon elongation deprives the gastrocnemius muscles of leverage and diminishes plantar flexion capabilities. Early mobilization after surgery slightly reduces elongation, and this correlates with better clinical outcomes.<sup>3</sup> But, even though such rehabilitation protocols are becoming more popular, it remains to be seen how much they'll actually improve patients' long-term function.

Few people know more about the interface between tendon evaluation and rehabilitation than Karin Silbernagel, PT, PhD, ATC. Silbernagel, a Swedish researcher and coauthor of many of the relevant papers, is now an assistant professor in the Department of Physical Therapy at the University of Delaware.

"There may be less extreme elongations in surgically treated patients, but there's still a difference between the injured and uninjured leg," Silbernagel said. "In our research, we're trying to determine whether early mechanical loading will make things better; if so, it probably has to happen within the first two or three months. But you can't just do more; you have to do the right things."

Silbernagel acknowledged that no one yet knows how to gauge when early loading is too early—when help becomes harm.

"Our lab is working on biomarkers that help us understand how mechanical properties change during healing, because when we know that, we can start implementing early exercises," she said. "The specifics of dosage will be important; many repetitions may stretch the tendon too much."

Like many clinicians, Silbernagel uses ultrasound to assess tendon length, thickness, and so forth. But it has its limitations.

"It doesn't tell me anything about the mechanical proper-



Karin Silbernagel, PT, PhD, ATC, and Daniel Cortes, PhD, use ultrasound to examine a patient's Achilles tendon. (Photo courtesy of Karin Silbernagel, PT, PhD, ATC.)

ties of the tendon—how strong it is or how it changes over time," she explained.

When tendons heal, compositional and structural changes lead to localized differences in the viscoelastic properties of the tissue. Existing attempts to measure these things tend to be invasive, such as the perioperative implantation of tantalum beads that allow roentgen stereophotogrammetric analysis.<sup>4</sup> Despite its drawbacks, the technique has shown significantly larger strain variations in patients treated nonsurgically than surgically.<sup>5</sup>

Ideally, however, such variables could be measured without implanting radioactive substances into the tendon stumps. Silbernagel and her colleagues believe they're on the track of such a technique; it's called continuous shear-wave elastography (cSWE) and it's so new the papers about it are hot off the press.<sup>6,7</sup>

The technique calculates viscoelastic properties by applying continuous shear waves with an external actuator, then measuring the wave speed at different excitation frequencies. For the first time, it allows researchers and clinicians to measure the viscoelastic properties of tendons in vivo.

"This may help evaluate tendon recovery, compare the effectiveness of different therapies, and devise patient-specific therapy programs," Silbernagel said. "Ideally, when we work with patients to build their strength, the body might be able to adapt to longer tendons. I think early physical therapy—mechanical loading of the tendon within the first three months—is crucial. So if we can use this new technique to track and adapt the effect we're having, there may be significant benefits." —CG

References are available at [lermagazine.com](http://lermagazine.com)

later than four weeks found rerupture rates were slightly higher in the surgical patients (6%) but lower in the nonsurgical group (10%). Neither between-group difference was statistically significant.

In the third category—rehab regimens in nonoperative patients—Danish researchers conducted an RCT comparing full weightbearing from day one to nonweightbearing for six weeks.<sup>17</sup> After a year, those in the weightbearing group had a better ATRS score, though rerupture rate was 9% in both groups, and both retained functional deficits in the injured limb. In a later analysis of biomechanical data from the same study, the researchers reported increased stiffness of the plantar flexor muscle-tendon complex in the nonweightbearing group at one year.<sup>18</sup>

“We concluded that weightbearing improved quality of life and did not have detrimental effects on functional outcomes,” said Kristoffer Barfod, who was the lead author of both papers.

Other clinicians described their preferred rehabilitation regimens to *LER*. David Richardson keeps his patients nonweightbearing for two weeks, then has them bear weight as tolerated in a boot with a triple (3") heel lift. After the initial two weeks in the boot, patients can remove it and work on general ROM, stopping if they feel pain or reach neutral (90° of ankle dorsiflexion).

“Each two weeks they remove one of the one-inch heel lifts, and they come out of their boot at about eight weeks,” he said. “That’s when they begin more aggressive physical therapy, but I keep them in a brace with a small heel lift until twelve weeks.”

Lowell Weil leaves his postoperative patients in a nonweightbearing cast for two weeks, then switches them to a removable boot with slight equinus (plantar flexion). “I start them with gentle physical therapy at two weeks—range of motion and muscle stimulation—then at twenty-eight days postop I let them fully weightbear with a small heel lift in their walking boot,” he said. “At six weeks they return to gym shoes.”

Practitioners should get patients moving as soon as safely possible, Stuart Miller said.

“It provides a better environment for tendon healing and makes for a stronger tendon later,” he said. “After surgery, I only keep them immobilized for the first week, then I put them in a boot. They can come out of that to plantar flex–dorsiflex three times a day so they don’t scar down. Then, when we start formal physical therapy at six weeks, they already have almost all their motion back.”

Miller admitted that he handles nonsurgical cases more delicately.

“We’re hesitant to stretch them too quickly,” he said. “Some people start moving them gently at two or three weeks, others wait a month. I don’t know what that magic number is.”

Jonathan Chang added that, for him, the quality of initial treatment is the most important factor in rehabilitation.

“If you’ve done a solid repair you can feel comfortable pushing them a little bit because the repair itself isn’t going to be the limiting factor,” he said.

These variations in rehabilitation protocols indicate the degree to which clinicians rely on experience and observation to produce individualized treatment plans for their patients. But there are innovations on the horizon (see sidebar) that may soon provide more objective measures. 

*Cary Groner is a freelance writer in the San Francisco Bay Area.*

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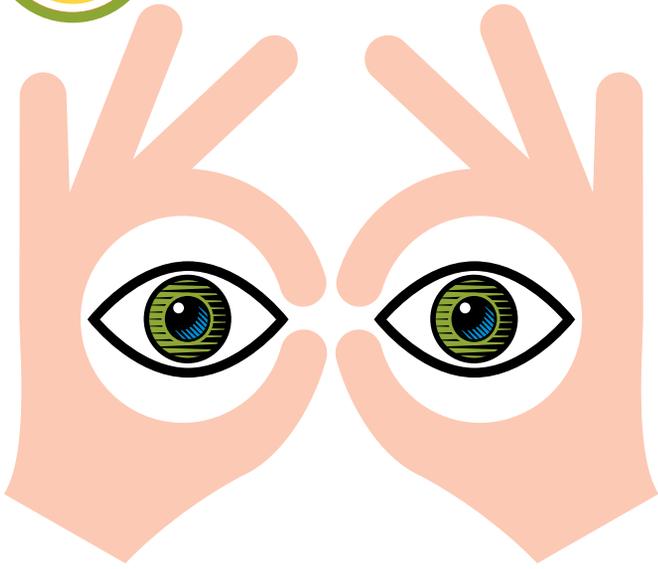
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By Cary Groner

“The most consistent advice I’ve received is that I have to come up with a better story about how this happened,” said David Armstrong, DPM, MD, PhD.

He was talking on the phone at his desk, his feet up, an ice bag on his mending left knee. Armstrong, a professor of surgery and codirector of the Southern Arizona Limb Salvage Alliance (SALSA) at the University of Arizona College of Medicine in Tucson, was a month out from serious injury, but all things considered he seemed fairly jolly. Not that this would come as a huge surprise to anyone who knows him.

A meniscal injury gave one practitioner new insight into the patient experience and renewed his belief that healing isn't just about what happens physically.

“Sitting really is the new smoking,” he said with a laugh. “It’s a serious hazard to your health. I was sitting at my desk, writing a paper, when I got called down to the operating room [OR]. I leapt up from the chair like Athena springing fully formed from Zeus’ brow—I’m sure that’s how it must have looked, one of those really awesome things. But instead of tearing my Achilles tendon, which would have been the Greek thing to do, I ended up tearing my meniscus.”

Armstrong felt the sear of pain and knew something was seriously wrong, but he’s a surgeon; he still had to go to the OR. The bucket-handle tear kept his knee from extending past 30°, so he went looking for some form of support to make his way downstairs.

“You’d think in the top place in the world for pressure relief on

## Surgeon finds himself on other end of scalpel

extremities, I’d be able to find something to protect and offload my leg,” he said. “But here I was, hopping around on my other leg, and the only thing I could find was a four-leg walker, the kind octogenarians use. So I grabbed it and went clacking down the hallway on one foot, heading for the OR.”

He finished the surgery, then did another one, mainly by sitting down. Afterward, he left the OR and drove over to the orthopedic clinic, where he found the kind of empathetic response he’d been hoping for.

“My buddies were just merciless,” he said. “No sympathy at all. I got an MRI—then we knew the meniscus was torn—but of course this was a Friday and that night we were having a party for sixty or seventy people, to welcome the new residents and fellows, at our house.”

By then, at least, he could save face by showing up on crutches instead of teetering in on the walker. He enjoyed the party—which doubled as a send-off for his longtime assistant Sandy Perry—then went back to the OR the next day, this time as a patient.

### Under the knife

He’d done thousands of surgeries in his career, but this was his maiden voyage on the other end of the scalpel. It was quite a trip, in fact, and like all good voyages ended up taking him someplace he’d never expected to go.

“They say don’t have surgery at your own hospital because everyone knows you,” Armstrong continued. “Everyone was making fun of me—‘How could you be so fragile that you fall apart standing up from your desk?’—and all the circulating nurses were stopping by. Then the anesthesiologist, Wally Nogami, came in, and with his flat Hawaiian affect, said, ‘David, you are really hard to kill.’ That’s the last thing I remember.”

The meniscal repair surgery went well, although when he awoke, the anesthesia had left him so nauseated that he began to vomit. His wife and daughters told him he looked like Linda Blair in *The Exorcist*, letting the green goop fly. Fortunately, a scopolamine patch forestalled the need for intervention by Max von Sydow.

Day two, home from the hospital: Armstrong was wearing an “awesome RoboCop leg brace,” but soon noticed aspects of it that suggested opportunities for improvement, as he tactfully put it. So in characteristic fashion, working with a phone and a laptop from his chair, he began the process by calling his friend Marvin Slepian, MD, a world-renowned Arizona cardiologist who designed the first artificial heart. They chatted on FaceTime, then Armstrong filed a patent application for several modifications to the brace to improve the wearer’s mobility and the ease of donning and doffing, among other things.

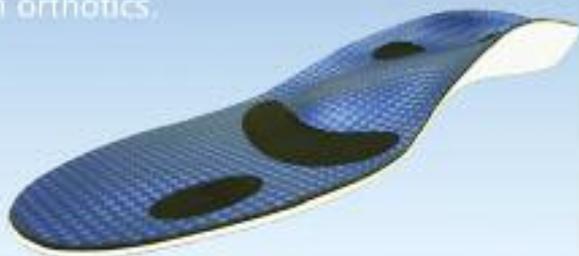
“That chair now has a serious butt print because I’ve spent so much time in it in the past few weeks,” he said, laughing. “I felt like I was in *Rear Window*, except my window was a computer screen.” The transition from Linda Blair to Jimmy Stewart had to feel like an improvement, anyway.

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Continued from page 29

When it was time to remove the stitches, Armstrong enlisted a little help from his wife, Tania, and his daughter Alexandria, and did it himself at home.

"I'd never trust an orthopedist to take out my stitches," he joked. "There's an old saying: Those guys are strong as an ox and twice as smart."

At four weeks out, Armstrong reported seeing advances in his mobility and motion every day.

"It's fun—it's like watching your kids grow up, only it's you instead," he said. He hasn't needed much in the way of painkillers, though he did take a Motrin in anticipation of the phone interview with this reporter, as a prophylactic against inflammation of the vocal chords.

## Taking time

Perhaps not surprisingly, one thing he'd noticed was how long it took him to get around.

"I usually have everything timed," he said. "I know exactly how long it takes me to get from point A to point B in the hospital. It usually takes two minutes and forty seconds to get from my desk to Pre-Op; it's a little bit of a distance but I walk quickly and say hello to people on the way. Now it takes twenty minutes, so I have to factor that in."

Not all of the delay is physical; Armstrong is beloved by colleagues and gets stopped so often that he's considered making a recording of his explanation and playing it as he limps along. Trips to the main university campus require a short drive instead of a 10-minute walk, and he won't be able to do stairs, except in peg-leg fashion, for another couple of months.

Rehab has been relatively uneventful, mercifully.

"I had my first real physical therapy appointment today," he said. "I've been working on a sled machine and I'm going to start some bicycling. I've been doing leg lifts and all these things you have to do if you're extremely decrepit. But the therapist down there is like: 'Oh come on now, sir, just a little bit more,' and boy do I feel old."

He was finally able to dress himself for the first time the day before we spoke.

"The last challenge was the sock on my left foot," he said. "It's deceptively difficult. I'm sure millions of people have gone through this and understand it, but I haven't. So I finally got my sock on and was so proud of myself—the big achievement!"

Armstrong usually keeps a busy travel schedule but it's on hold for the time being. A trip to lecture in Mexico had to be canceled. He's lecturing to University of Arizona surgical students in person, though, and to students at Cardiff University in Wales via the Web.

"Next week I'm supposed to travel, but we'll see," he said. "I may violate someone's explicit instructions." (Editor's note: At press time, in late October, Armstrong was back on the road in Toronto.)

## Bringing things full circle

With the doctor on crutches for a change, Armstrong's patients have developed a new appetite for selfies with him, and many of them want him to try their gear.

"One guy had this fancy automatic wheelchair, and I couldn't drive it for hell. I kept banging into all the walls and nearly wrecked the clinic," he said. "But the whole thing's been a blessing, really,

Continued on page 32

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Figure 1: Armstrong speeds down to the OR minutes after sustaining a high-energy knee injury by leaping from his chair.



Figure 2: Armstrong is sympathetically assisted to the men's restroom by (L-R) trauma physician Rifat Latifi, MD, heart surgeon Zain Khalpey, MD, PhD, and bioengineer Bijan Najafi, PhD, at the University of Arizona Medical Center.



Figure 3: Armstrong gets tips on driving a motorized wheelchair from his patient Steve Frederick.

because it's allowed me to experience what it's like from the patient's side. As doctors and nurses and physical therapists and pedorthists and orthotists, we think we know that, we act like we know. But it's a whole different thing when you really know. It brings things full circle."

From that new perspective, Armstrong feels more strongly than ever that healing isn't just about what happens physically.

"What I've found is that outlook and affect are inexorably associated with outcome," he said. "I'm not just talking about myself and my knee, I'm talking about my patients. Every time this hurts a little bit, I

look at my patients. These people have been through so much—orders of magnitude more significant than this—and they handle it with such grace and dignity. I look at the dignified way people heal and age, and frankly, the dignified and brave way people die. These are things I see every day because our patients are really sick. So I think about the three little holes in my knee, and it's like: Come on, man, big deal. I'm doing great, I had a great doctor, I have it easy." 

*Cary Groner is a freelance writer based in the San Francisco Bay Area.*



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<sup>1</sup>Hill RS: Ankle equinus: prevalence and linkage to common foot pathology. *JAPMA*. 1995; 85(6):295-300.

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## Equinus: Its surprising role in foot pathologies

Although milder than the spasticity-induced cases of equinus, limited ankle dorsiflexion in the non-neurological population is increasingly recognized as a source of excessive strain throughout the foot and a factor in the pathogenesis of many foot conditions.

By Nicholas V. DiMassa and Jeffrey M. Whitaker DPM, FACFAS

Equinus has been investigated extensively throughout the literature, and can be described as an inability to dorsiflex the ankle joint enough to allow for normal pain-free ambulation. Equinus of the foot is the most common deformity in children with spastic cerebral palsy and, as early as the 1920s, Swedish orthopedic surgeon Nils Silfverskiöld advocated the use of a gastrocnemius recession as a way to treat cerebral palsy patients who suffered from a contracture of the posterior calf muscles.<sup>1,2</sup> Practitioners, however, are beginning to emphasize a form of soft tissue equinus that occurs as a result of an isolated contracture of the gastrocnemius muscle in the healthy adult population.<sup>3-5</sup>

Although milder than the spastic neuro-induced cases of equinus, the gastrocnemius contracture in the non-neurologically impaired population is being highlighted as a source of deformity that will lead to excessive strain throughout the foot. It is thought to be a primary factor in the pathogenesis of many common pedal ailments, including plantar fasciitis, hallux valgus, metatarsalgia, Achilles tendinopathy, fatigue of the anterior extensor muscles, ulcers, and a variety of other pathologies that are seen in clinics daily.<sup>3,5-7</sup>

The reported prevalence is astounding. In a 1995 article in the *Journal of the American Podiatric Medical Association (JAPMA)*, Hill stated that 96.5% of examined patients in his clinic had reduced ankle joint dorsiflexion requiring compensation during gait.<sup>8</sup> Patel and DiGiovanni corroborated that finding by evaluating every patient that presented with either acute or chronic plantar fasciitis. They revealed that 83% of patients suffered from equinus, with 57% being diagnosed as an isolated gastrocnemius contracture.<sup>9</sup>

### Identification

The superficial posterior crural compartment is separated from the deep posterior compartment by the deep transverse fascial septum of the leg. The muscles of the superficial posterior compartment are powerful plantar flexors of the ankle joint and include the

Although definitions of equinus vary, the literature generally recognizes equinus as being present when the patient is unable to achieve 10° of ankle joint dorsiflexion.



Figure 1. If the patient is able to achieve more ankle dorsiflexion with the knee flexed (top) than with the knee extended (bottom), an isolated gastrocnemius contracture is likely. If knee flexion does not significantly affect the degree of ankle dorsiflexion, then a gastroc-soleus complex equinus is likely.

gastrocnemius muscle and the soleus muscle. Together, the gastrocnemius and soleus are referred to as the triceps surae. The triceps surae originates from three separate heads and converges into the Achilles tendon, which serves as the combined attachment of the gastrocnemius and soleus muscles onto the posterior portion of the calcaneus.

Calf muscle tightness is generally an inherited trait that manifests later in life, but can also be caused by nerve injuries, diabetes, and stroke.<sup>10,11</sup> According to Hill, the high incidence of equinus points to “acquired deformity” related to lifestyle factors that leave the calf muscles at a physiologic disadvantage.<sup>8</sup> In 2002, DiGiovanni and colleagues authored a study that showed 88% of healthy patients with forefoot or midfoot pathologies or both presented with posterior muscle group tightness.<sup>5</sup> More specifically, they, like others, found the majority of the patients suffered from an isolated gastrocnemius equinus, as opposed to a gastroc-soleus complex equinus.<sup>3-6,9</sup>

Although equinus is defined as the inability to dorsiflex the ankle joint enough to allow for normal motion, there is not an

absolute consensus on the degree of dorsiflexion necessary for normal pain-free ambulation.<sup>5,10,13</sup> The literature generally recognizes equinus as present when less than 10° of ankle joint dorsiflexion is attainable.<sup>10,13</sup> Using the Silfverskiöld test makes it possible to determine whether the tightness originates from the gastroc-soleus complex or strictly due to an isolated contracture of the gastrocnemius muscle.<sup>2,10</sup>

To perform the exam, clinicians should position the foot and ankle in a position mimicking the point in the gait cycle when the most ankle dorsiflexion is required. This can be done with the patient in a supine position and the knee fully extended. The examiner places the foot in a subtalar joint neutral position, eliminating any supination or pronation. Congruity should be felt on both the medial and lateral sides when the navicular is centered on the talus. A dorsiflexory force should be applied to the foot, concentrated on the medial aspect to avoid pronation, until maximum dorsiflexion is achieved. To measure the degree of dorsiflexion, a goniometer or tractograph can be used. The reference lines for the measurement should be the bisection of the lower third of the lateral aspect of the leg and the plantar surface of a line correlating with the fifth ray.<sup>6</sup> The test is then repeated with the knee in a flexed position using the same reference lines and technique.

If the patient is able to attain sufficient dorsiflexion (typically about 10°) when the knee is flexed, but not when it is extended, the equinus is determined to be an isolated gastrocnemius contracture, likely due to a contracture in the muscle belly or aponeurosis.<sup>2,5,14</sup> If, however, the patient is not able to achieve more dorsiflexion with the knee flexed than with it extended, then the equinus is said to be a gastroc-soleus complex equinus and is most likely due to an osseous deformity or contracture within the Achilles tendon itself.<sup>10</sup>

## Compensation and gait changes

Many pathogenic manifestations of equinus occur due to the center of pressure displacement that is seen in diseased states. Typically, the center of pressure on the foot can be measured 6 cm anterior to the ankle during gait, but with equinus, it is shifted distally and laterally.<sup>15,16</sup> The pull of the Achilles tendon cannot adequately compensate for the new distal and lateral center of pressure and, as a result, an overall pronatory force remains.

Generally, three stages of compensation due to equinus are recognized clinically. In an uncompensated equinus, the patient will appear to walk on the toes or ball of the foot, with the heel appearing to float off the ground.<sup>15,17</sup> This is the most drastic manifestation, and accounts for a very small percentage of cases. While it can be seen in someone suffering from an isolated gastrocnemius equinus, it is more often indicative of a spastic cerebral palsy induced equinus. Pathologies expected in the true toe-walker include submetatarsal tylomas and digital contractures due to the need for extensor substitution.<sup>13</sup> By and large, gastrocnemius-related equinus is seen in its partially compensated or fully compensated forms, which can make it more difficult to identify.

Compensations for the tightness in the calf can occur proximally and include genu recurvatum, flexion of the hip, and lumbar lordosis.<sup>15,19,20</sup> Early heel-off will be noted in a partially compensated equinus and appear as a “bouncing gait.” In fully compensated equinus, the foot will likely appear severely pronated with abnormal abduction and dorsiflexion needed to allow the heel to rest on the ground. Often, midfoot and first ray hypermobility can be noted due

Continued on page 38

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to unnatural dorsiflexion at the naviculocuneiform and tarso-metatarsal joints. A weakening of the pull of the peroneus longus muscle leads to an inability to lock the midtarsal joint and has been attributed to such causes of medial column hypermobility.<sup>13,21</sup> These compensations have been shown to be associated with a variety of foot pathologies, including neuropathic ulcers, metatarsalgia, hallux abducto valgus, and even Charcot neuroarthropathy in patients with diabetes.<sup>22</sup>

## Treatment

Treatment for equinus should be aimed at increasing ankle joint dorsiflexion to facilitate normal gait mechanics. In most cases, nonspastic forms of equinus tend to be more treatable and easily corrected than the spastic neuro-induced forms of equinus.<sup>13</sup> A variety of conservative measures can be employed, including stretching, bracing, and orthotic devices.

The merits of manual stretching for the gastrocnemius muscle have been a topic of debate, but studies have demonstrated that favorable results are possible when stretching is done correctly even for short time periods. Grady and Saxena found that manual stretching for five minutes per day over six months increased dorsiflexion by an average of 2.7°.<sup>23,33</sup> Similarly, Macklin and colleagues were able to elicit excellent results in a group of runners with equinus contractures. Their results produced an average increase in ankle joint dorsiflexion from 5° to 16° following an eight-week stretching program.<sup>24</sup>

For stretching to be effective, it has been recommended that it be done with the foot adducted to allow for locking of the subtalar

and midtarsal joints.<sup>25,26</sup> With the subtalar and midtarsal joints locked, distal compensatory mechanisms arising from hypermobility along the first ray and an abnormally dorsiflexed naviculocuneiform joint are minimized so the stretching is primarily focused on the posterior calf musculature. Recent studies, however, have shown that an increase in dorsiflexion can be achieved regardless of whether the foot is stretched in a pronated or supinated position.<sup>27-29</sup> In addition to stretching, night splinting can be employed. A 2001 study in *JAPMA* demonstrated favorable outcomes in a series of cases

Clinical approaches that include treatment for secondary equinus will be inherently more successful than treatment limited to the presenting foot pathology alone.

that involved an element of equinus, when night splinting and stretching were used as a combination therapy.<sup>30</sup>

Distal compensations such as pronation at the subtalar joint and inappropriate unlocking of the midtarsal joint lead to pes planus deformities, which in some cases can be effectively managed with foot orthoses.<sup>31,32</sup> An effective orthosis aimed at correcting pes planus secondary to equinus should provide medial longitudinal arch support and correct the flexible nature of the deformity. A typical orthosis will include a medial wedge and, most importantly, a

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heel lift when equinus is present.<sup>32</sup> Patients will feel significantly more comfortable in shoes with an elevated heel, and will have the most difficulty ambulating barefoot or in sandals, flip-flops, or flat shoes that offer no additional elevation. Care should be taken to avoid conditions in which the rearfoot could sink below the forefoot, such as walking on the beach or in sand. An ankle foot orthosis (AFO) provides an option for the patient suffering from an equinus with an element of drop foot. AFOs improve walking and reduce the risk of falling in individuals with paretic dorsiflexory muscles, providing clearance through the swing phase of gait by limiting the speed of plantar flexion.<sup>33</sup>

When conservative measures fail to correct the deformity, there are a number of surgical options for management of equinus. It is important that the selected surgical procedure is tailored to the specific deformity. Again, using the Silfverskiöld test remains the most accurate way of distinguishing a global gastroc-soleus equinus from an isolated gastrocnemius equinus.<sup>2</sup>

Armstrong and colleagues, as well as Sgarlato et al, were proponents of a tendo-Achilles lengthening procedure.<sup>17,35</sup> The procedure is best for addressing a shortened tendon or osseous deformity that may be seen more often with a gastroc-soleus equinus than an isolated gastrocnemius equinus, but care must be taken to avoid complications including overlengthening, rupture, and loss of strength.

A gastrocnemius recession is typically reserved for patients with an isolated gastrocnemius contracture. Studies suggest the procedure is simple and effective, and addresses almost all complications associated with the tendo-Achilles lengthening procedure.<sup>36,37</sup> The biggest risk associated with gastrocnemius recession was injury to the sural nerve, which can be avoided with careful dissection and incision planning. Maskill and his partners reported in a 2010 study that 27 of 29 patients were satisfied with the results from the procedure.<sup>38</sup> Sammarco et al also reported on the outcomes of a gastroc-soleus recession, noting a statistically significant increase of ankle joint dorsiflexion averaging 18.3° in a group of 40 patients. In Sammarco's population, 38 of the 40 patients reported no pain at the incision site, while two patients had reports of paresthesia associated with the area of sural nerve distribution.<sup>36</sup>

## Conclusions

As the medical literature continues to show equinus is present in a majority of patient populations afflicted by common foot pathologies, it is crucial for practitioners to identify the influence of equinus in biomechanical evaluations. Therapeutic approaches that include treatment for secondary equinus will be inherently more successful than treatment limited to the presenting pathology alone. An accurate clinical assessment should be based on the amount of dorsiflexion present on exam. Conservative care should always be the staple of early treatment plans and should include stretching, splinting, and orthotic devices. If conservative care fails, gastrocnemius recession or tendo-Achilles lengthening procedures should be considered. 

*Nicholas V. DiMassa is a podiatric medical student and Jeffrey Whitaker, DPM, FACFAS, is the head of the Division of Podiatric Surgery and an associate professor in the Department of Foot and Ankle Surgery at Kent State University College of Podiatric Medicine in Independence, OH.*

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## Experts revisit hyperbaric oxygen for diabetic ulcers

Recent analyses cautiously recommend the short-term adjunctive use of hyperbaric oxygen therapy (HBOT) for diabetic foot ulcer healing under certain conditions, but in the absence of high-quality clinical trials, experts continue to debate the controversial therapy's benefits.

By Hank Black

The rationale for including hyperbaric oxygen therapy (HBOT) as an adjunctive therapy for diabetic foot ulcers may be a little clearer following developments in recent months, but controversy over its use shows no sign of going away soon.

Proponents of HBOT for diabetic foot ulcers are bolstered by a literature review from the Undersea & Hyperbaric Medical Society (UHMS) that found sufficient evidence to recommend its use in severe wounds and issue the group's first clinical practice guidelines for use of the therapy for diabetic foot ulcers.<sup>1</sup> And, in June, an updated Cochrane review of randomized controlled trials (RCTs) reached a cautiously optimistic conclusion about the treatment's short-term benefits.<sup>2</sup>

However, contradictory conclusions from other reviews have continued to muddy the HBOT waters: The Ontario Health Technology Advisory Committee (OHTAC) in August recommended against expanding public funding for the treatments,<sup>3</sup> and a month later, the International Working Group on the Diabetic Foot (IWGDF) published a systematic review that concluded lower limb practitioners should consider using the treatment for that indication, though they described the strength of that recommendation as weak.<sup>4</sup>

Hyperbaric oxygen treatments involve delivering near 100% oxygen to a patient in a hyperbaric chamber at typically 2 to 2.5 atmospheres for 90 to 120 minutes once or twice daily for 15 to 30 treatments.<sup>2</sup> Some elements of healing are very oxygen-dependent, and HBOT delivers an increased partial pressure of oxygen to the tissues.<sup>5</sup>

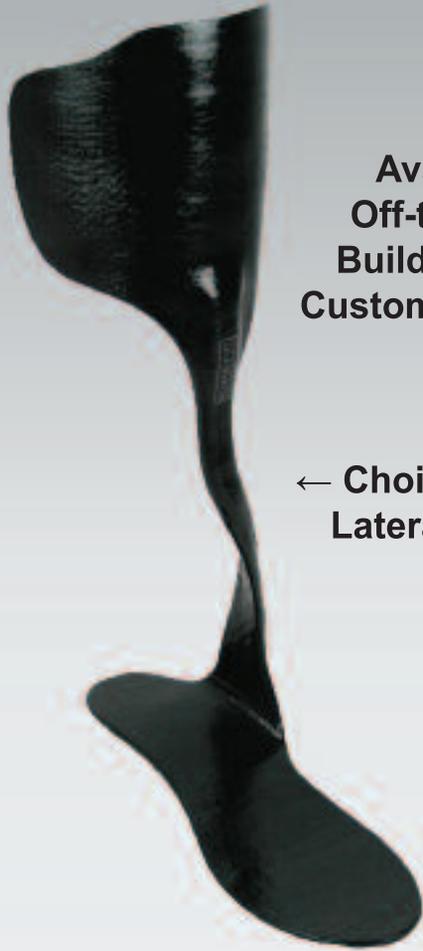
### Better studies needed

The source of the disagreements about HBOT is acknowledged by what has become a standard disclaimer in most analyses: Recommendations are difficult to make because controlled studies remain few and continue to be of poor methodological quality, primarily with regard to the size and heterogeneity of the populations studied.

Practitioners and researchers are calling for more high-quality studies to confirm HBOT's cost-effectiveness and to identify the patients most likely to benefit from it.

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All parties call for more definitive studies to tease out the answers to primary questions.

Enoch Huang, MD, coauthor of the UHMS review and clinical practice guidelines, said the preponderance of research on HBOT for diabetic foot ulcers is positive, on balance, even if it's not robust.

"The literature provides enough objective data that we know HBOT works," Huang said. "But the question is who does it work best for? That's what we need to focus on: How do we effectively use the technology to treat the right patient at the right time?"

Huang is the medical director of wound healing and hyperbaric medicine at Adventist Medical Center in Portland, OR, where he utilizes a three-chamber hyperbaric facility that treats four to eight patients every weekday. He also is president of the UHMS.

He, like others, found that the "right patient" is difficult to define. The authors' final analysis included five RCTs and five observational studies.

"We could not pool every study because of the heterogeneity of the patient populations enrolled. The only common factor we could use to select studies was by wound severity and whether the wound was acute postoperative or nonhealing after thirty days or more of care. We used the Wagner wound classification scale,<sup>6</sup> which is not perfect, but no other system of wound categorization provided a basis for a prospective comparative study," Huang said.

The "right time" to treat a patient is also complicated, he said.

"We have been pushed by recent practice patterns to wait thirty days before starting HBOT. Our analysis determined HBOT helped healing but did not necessarily decrease the amputation rate. But, if we eliminated the waiting period to narrow the timeframe between when someone comes in with a bad foot and when HBOT is started, we saw a decrease in the amputation rate."

The UHMS selected four clinical questions for review of the role of HBOT in diabetic foot ulcers:

- Is HBOT with standard care more effective than standard wound care alone?
- Is it more effective in a patient with a Wagner Grade 2 (ulcer penetrating deeper than superficial layers but without abscess or osteomyelitis) or lower wound than standard care alone?
- How about a patient with a Wagner Grade 3 ulcer (deeper than superficial, with abscess or osteomyelitis)?
- And what about the patient with an ulcer of Wagner Grade 3 or higher who has just had a surgical debridement of the foot?

Critical outcomes for the review included major amputation and incomplete healing at one year.

The questions resulted in three recommendations:

- No HBOT in patients with diabetic foot ulcers of Wagner Grade 2 or lower (very low evidence supporting HBOT).
- Add HBOT to standard of care in patients with Wagner Grade 3 or higher wounds (moderate level of evidence supporting HBOT).
- Add HBOT in patients with Wagner Grade 3 or higher wounds who have just undergone debridement of an infected foot (moderate level of evidence supporting HBOT).

"It's very expensive to conduct a RCT for hyperbaric oxygen treatment of diabetic foot wounds, especially with enrollment numbers that will make a difference," Huang said. "However, the UHMS would be glad to coordinate multicenter trials and unification of protocols."

The Cochrane review published this year included an analysis of 10 RCTs with a total of 531 participants with diabetic foot ulcers,

up from eight trials and 455 participants in its 2012 review.<sup>7</sup> Analysis of data obtained from pooling five trials with 205 participants showed an improvement in ulcer healing rates with HBOT at six weeks (RR 2.35; 95% CI 1.19 to 4.62;  $p = .01$ ), a benefit not found at one-year follow-up. No significant difference was found in major amputation rates in five pooled trials with 312 people enrolled (RR 0.36; 95% CI .11 to 1.18).

The Cochrane and UHMS reviews have been welcomed by those who were discomfited by the 2013 publication in *Diabetes Care* of a large observational study by Margolis et al that found HBOT did not improve ulcer healing or reduce amputations compared with no HBOT.<sup>8</sup> Critics of that study have averred that many confounding factors may have led to selection bias: the majority of patients had less severe ulcers (Wagner Grade 2); follow-up was limited to 16 weeks; the proportion of those completing all hyperbaric treatment sessions is unknown; and it is not clear whether all patients had achieved optimal limb perfusion prior to receiving HBOT.<sup>9</sup> The observational study was large (6259 patients with non-ischemic diabetic foot ulcers), but its critics point out that it was based on retrospective data from one large, for-profit wound management company.

The shift of most HBOT care for diabetic foot ulcers to outpatient facilities, Huang said, is because the Centers for Medicare and Medicaid Services (CMS) mandates a 30-day period of standard wound care with no measurable signs of healing after diagnosis of a Wagner Grade 3 wound or higher before it will reimburse for the treatment (plus standard care),<sup>10</sup> effectively leaving inpatient treatments to be bundled with other charges.

## Wound classification

Michael B. Strauss, MD, an orthopedic surgeon at Long Beach Memorial Hospital in California and a coauthor of the UHMS practice guidelines, said the Wagner system should be replaced. Although the system is often used to grade wound severity in HBOT studies, he said, many practitioners and healthcare organizations find it archaic and some use other classification systems that provide more clinical information.<sup>11,12</sup>

Strauss said that hyperbaric treatments should be restricted to hospitalized patients, and that outpatient HBOT should only be used for those patients' continuity of care.<sup>13</sup>

Predicting which diabetic foot ulcers will heal with HBOT is an unresolved issue. Proper patient selection is mainly based on the severity of wound ischemia, and Löndahl et al found that baseline transcutaneous oxygen pressure correlates with response to treatment.<sup>14</sup> Fluorescence angiography is another predictive technology under investigation. The real-time imaging tool is based on use of the short-lived fluorescence agent indocyanine green that absorbs light in the near-infrared spectrum. Huang said his group is performing microvascular perfusion studies using fluorescence angiography, and Georgetown University is designing a study to see whether that technology can help determine when vascularity has improved to the point that HBOT can be discontinued.

"We do need more evidence for diabetic foot ulcer treatment with HBOT; however, what we have is promising, and we plan to be contributing to the research effort," said Kelly Johnson-Arbor, MD, medical director of MedStar Georgetown University Hospital Department of Plastic Surgery's four-chamber hyperbaric oxygen facility in Washington, DC.

*Continued on page 44*

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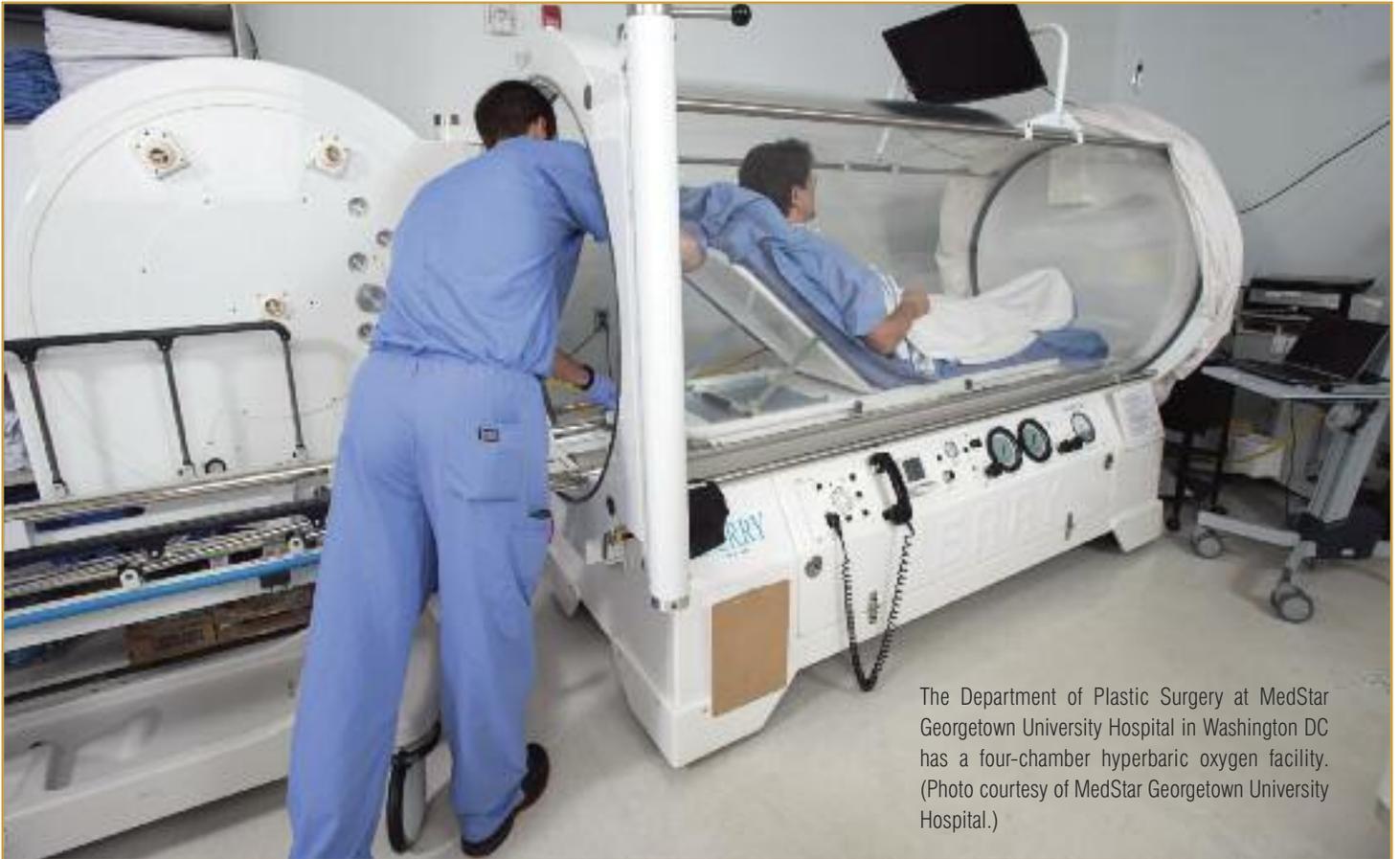
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The Department of Plastic Surgery at MedStar Georgetown University Hospital in Washington DC has a four-chamber hyperbaric oxygen facility. (Photo courtesy of MedStar Georgetown University Hospital.)

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## Potential for abuse

The trend of conducting outpatient HBOT in wound care facilities is also thought to have increased and worsened abuse of the system, according to Phi-Nga Jeannie Le, MD, a hyperbaric and emergency medicine physician in Houston, TX. Le assisted the federal government in its successful prosecution of principals of a HBOT company for conspiracy to commit healthcare fraud, which included double billing. The parties pleaded guilty to the charges and in 2014 were sentenced to five years in prison and ordered to pay millions of dollars in restitution.<sup>15</sup> And, as recently as September 30, a federal district judge in Florida unsealed a False Claims Act suit involving HBOT against one of the nation's largest wound care companies.<sup>16</sup>

Le, who practices emergency and hyperbaric medicine at multiple hospitals in Houston, TX, recently analyzed several healthcare fraud cases that have involved inappropriate use and documentation issues at facilities conducting hyperbaric oxygen treatments.<sup>17</sup> She said that, for a relatively new specialty and the comparative number of patients who receive HBOT yearly, the industry is seen by the federal government and prosecutors as having a high rate of healthcare fraud.

"Lack of self-policing and poor uniform adherence to standards in the field have enabled corporations and individuals to be tempted to find an alternative way to bill for HBOT or gain reimbursement in improper ways," Le said. "Hyperbaric medicine centers, individual physicians, hospitals, and other entities that administer HBOT appropriately are tainted by the fraud and disreputable activities that have stigmatized an entire industry."

She also said HBOT introductory courses conducted by wound management companies and marketed to physicians as training programs have led to the misrepresentation of so-called "certification" and qualifications of physicians in hyperbaric medicine. The courses, she said, make physicians vulnerable to conflicts of interest and to coercion.

"Physicians who only undergo a forty-hour introductory course in HBOT sponsored by private, for-profit companies, thinking that this is all they need to become qualified to practice, are ill-equipped to present themselves as hyperbaric medicine specialists," Le said.

## A patient-centric role

David G. Armstrong, DPM, MD, PhD, professor of surgery and codirector of the Southern Arizona Limb Salvage Alliance (SALSA) at the University of Arizona College of Medicine in Tucson, said HBOT has a role in treating diabetic ulcers.

"Yet, I don't think that place is for but a fraction of the millions of diabetic wound patients around the world," Armstrong said. "I believe our really progressive colleagues operating HBOT-centric wound healing centers are now converting those into patient-centric wound healing, reconstruction, and risk-reduction units that may also include HBOT. That would help move us from volume-based to value-based care."

Armstrong also is concerned about the amount of time patients must devote to the treatment.

"Going into a hyperbaric chamber for sixty to ninety minutes a day for a month or two is really hard on patients—regardless of which movie is playing on the DVD," he said. "We need to think hard about the patient-centric aspects of this care and continue to try to improve it."

*Continued on page 46*

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Those treatment sessions may be put to good use: Johnson-Arbor said she is preparing a study to determine if delivering focused diabetes education to patients during the in-chamber treatment period can result in improved blood sugar control.

In Ontario, as noted above, the OHTAC recently recommended against expanding the use of public funding for HBOT in the treatment of diabetic ulcers of the lower limb.<sup>3</sup> Its report to the Ontario Ministry of Health and Long-Term Care was based on findings from three studies. One is a 2013 *Mayo Proceedings* systematic review that concluded HBOT improves healing rates and reduces lower extremity amputations in patients with diabetes compared with no HBOT.<sup>18</sup> The other two—a systematic review published in 2013<sup>19</sup> and a clinical trial<sup>20</sup> developed from that review—originated from the Programs for Assessment of Technology in Health (PATH) Research Institute at St. Joseph’s Healthcare Hamilton in Ontario.

PATH’s literature review concluded HBOT might reduce risk of

Photo courtesy of Sechrist Industries.



major amputation, but the effect was not statistically significant in a pooled analysis of six RCTs. Results of the PATH RCT have been submitted for publication, according to Daria O’Reilly, MD, MSc, associate professor of clinical epidemiology and biostatistics at McMaster University in Ontario and chair of the study.

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The 103-patient trial found no significant difference in the rates of healing and major amputation between patients with diabetic ulcers randomized to HBOT and those randomized to sham treatment. Public comment on the OHTAC recommendations closed on October 15.

So the push-and-pull over HBOT continues. In September, a panel of the International Working Group on the Diabetic Foot (IWGDF) recommended that practitioners should consider the use of systemic HBOT for diabetic foot ulcers. The group's 2012 review<sup>21</sup> had provided some evidence to suggest that HBOT may reduce the rate of major amputation. In its latest review, which included three small nonblinded RCTs<sup>22-24</sup> and the observational study by Margolis et al,<sup>8</sup> the panel of experts on wound healing found little high-quality evidence to add to the discussion.

The organization echoed the many calls from practitioners and researchers for more high-quality RCTs to confirm the treatment's cost-effectiveness and to identify the population most likely to benefit from its use.

Georgetown University's Christopher Attinger, MD, interim chair of the Department of Plastic Surgery and a member of the IWGDF panel, said, "Much like the IWGDF, I am not sure of the role of hyperbaric oxygen in the diabetic foot."

## Trials in the pipeline

The HBOT community can look forward to results from at least two multicenter RCTs in the near future, although they will study different populations and thus not by themselves resolve the heterogeneity issue that has made data comparison and pooling a challenge. One is PATH's unpublished study, which enrolled patients without large vessel disease who are not candidates for revascularization. The other is the Dutch DAMOCLES (Does Applying More Oxygen Cure Lower Extremity Sores) trial, which will study HBOT's ability to increase wound healing and prevent amputations in patients with ischemic diabetic ulcers, as well as whether the treatment is cost-effective.<sup>25</sup> The rationale for DAMOCLES came from a 2014 systematic review conducted by the researchers, which found some evidence of the effectiveness of HBOT for this population.<sup>9</sup>

"DAMOCLES definitely has the potential to emphatically cement the place of HBOT in the treatment of diabetic ulcer," said Michael H. Bennett, MD, a coauthor of the recent Cochrane review and head of the Diving and Hyperbaric Medicine Research Program at the Prince of Wales Clinical School in Randwick, Australia. "I am not aware of any major methodological flaws. It's a large trial and will have good power to more accurately determine the true impact of HBOT on these patients."

Bennett said he is encouraged to see the cost-effectiveness analysis included in the study plan, as few previous studies have done. Two commonly cited studies found the cost of HBOT was more than offset by reductions in other costs, such as office visits, dressings, and major amputations.<sup>26,27</sup>

Another Cochrane author, Peter Kranke, MD, MBA, professor in the Department of Anesthesia and Critical Care at University Hospitals of Wuerzburg in Germany, seemed less sure.

"I am a bit pessimistic that new and much better evidence will come up in the near future," Kranke said. 

Hank Black is a freelance writer in Birmingham, AL.

References are available at [lermagazine.com](http://lermagazine.com).

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## Quadriceps symmetry after ACL reconstruction

Using muscle function symmetry as an indicator of patient progress after anterior cruciate ligament (ACL) reconstruction can provide insight about potential targets for intervention to improve movement quality, functional performance, and patient outcomes.

By Christopher Kuenze, PhD, ATC; and Adam Kelly, MS, ATC

The goal of anterior cruciate ligament reconstruction (ACLR) is to improve knee joint stability following ACL injury to facilitate a return to preinjury levels of physical activity or sports performance.<sup>1</sup> Unfortunately, this clinical approach often comes with potential costs in the form of persistent neuromuscular and movement dysfunction that can be difficult to evaluate and treat in the clinical setting.<sup>2</sup> Although comprehensive rehabilitation following surgery is meant to address these potential issues, it's often difficult for clinicians to effectively monitor patient progress because they lack information about the patient's preinjury functional status and level of performance. This can pose a significant challenge in setting clinical goals for the patient, as well as for making informed decisions regarding rehabilitation progression for a safe return to physical activity or sports.

In the absence of preinjury physical assessment data clinicians often use the uninjured or contralateral limb as a stable reference for comparison.<sup>3</sup> In the literature, limb symmetry assessments have been reported for measures of muscle function, biomechanics, and functional performance following ACLR.<sup>4</sup> The ideal approach to prospective assessment of physical function following ACLR would include comparison with preinjury data or normative data for a matched population, but this is largely unrealistic for most measurements or assessments used in the clinical setting. The use of limb symmetry as an indicator of patient progress has been supported in the literature and, despite some limitations, has provided insight into potential targets for intervention that can positively impact movement quality, functional performance, and patient outcomes.

### Quantification of limb symmetry

There are several common approaches to assessing limb symmetry, all of which have strengths and weaknesses that depend on the goal of the assessor. Subtracting a measurement of the injured limb from the corresponding measurement of the healthy contralateral limb

Limb symmetry indices may allow clinicians to better quantify and compare persistent alterations in muscle function, movement patterns, and functional performance.

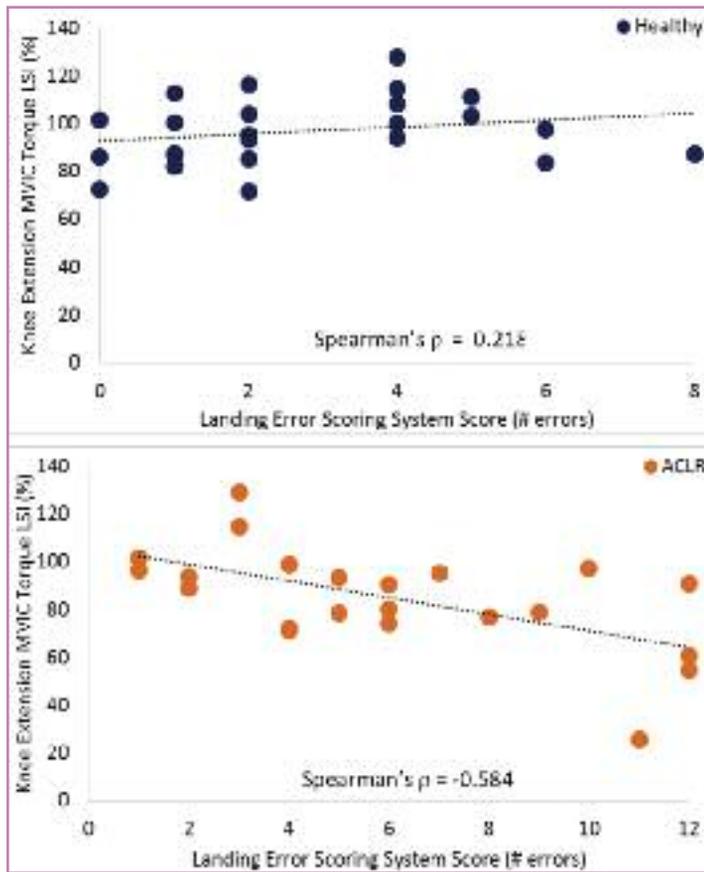


Figure 1. The relationship between knee extension MVIC torque symmetry and Landing Error Scoring System score. There is a significant moderate relationship ( $\rho = -0.584$ ) between less knee extension MVIC torque asymmetry and more landing errors among those with a history of ACLR, while no relationship exists among healthy participants.

is a simple and commonly used estimation of asymmetry or between-limb differences. Despite its ease of use, it does not adequately account for the scale of the measure being taken.

The use of limb symmetry indices (LSI, Equation 1) has become commonplace in practitioner attempts to better understand the magnitude of symmetry between limbs relative to the scale of the assessment of interest.<sup>3,5,6</sup> In this case, the between-limb difference is now represented as a percentage of the healthy limb measurement, which enables the clinician to compare symmetry directly between different assessments regardless of the scale of the units of measure. For example, a clinician would be able to directly compare symmetry estimates for range of motion and strength for an individual, since LSI in each case would be expressed as a percentage, despite the fact that one is measured in degrees while the other is measured in newtons or foot-pounds.

$$\text{Equation 1. LSI} = \left( \frac{\text{injured limb}}{\text{healthy limb}} \right) \times 100$$

## Our corticomotor research

Unilateral and bilateral deficits in quadriceps strength and activation have been widely reported in the months and years following ACLR.<sup>7,8</sup> The exact source of this dysfunction has been elusive, but neural inhibition at the cortical and spinal levels and muscle atrophy have been implicated as primary contributors.<sup>2,8,9</sup> Previous research

investigating the importance of symmetry in quadriceps strength and activation following ACLR has established a number of thresholds for adequate or ideal quadriceps functional symmetry. Most often studies report that 85%<sup>4</sup> or 90% symmetry<sup>10,11</sup> is indicative of good bilateral quadriceps function and functional performance. These scores are predictive of strong patient-reported knee-related function, as well as symmetry in performance on functional testing such as single-leg hopping.<sup>12-14</sup> Unfortunately, the source of asymmetry and the potential targets for clinical intervention in patients with persistent quadriceps dysfunction is still unclear.

Our recent work has focused on the symmetry of neuromuscular and corticomotor measures of quadriceps function among patients with a history of unilateral ACLR, as well as healthy controls.<sup>8</sup> The primary goals of this research were to confirm that neuromuscular and corticomotor symmetry in quadriceps function is present in healthy individuals and to quantify the level of asymmetry in clinical and laboratory-based measures of quadriceps function among physically active patients with a history of ACLR.

To better understand the potential sources of symmetry in isometric knee extension strength following ACLR, we chose to investigate symmetry in cortical excitability via transcranial magnetic stimulation (TMS), spinal reflex excitability via the quadriceps Hoffmann reflex (H-reflex), and a global measure of quadriceps activation via the quadriceps central activation ratio (CAR). We found that patients with a history of ACLR (time since surgery =  $31.5 \pm 23.5$  months) who had returned to physical activity persistently experienced greater asymmetry in quadriceps strength, quadriceps activation, and cortical excitability, but not in spinal reflex excitability, compared with a similar group of healthy participants.

Our findings related to quadriceps strength and activation were consistent with those of previous investigations;<sup>7,11</sup> however, this was the first time that asymmetry of quadriceps function was linked to cortical sources of asymmetry in those with a history of ACLR. While not included in the published study, subsequent reanalysis of this dataset revealed a moderate relationship between symmetry of cortical excitability and symmetry of both quadriceps strength ( $\rho = .417$ ) and activation ( $\rho = .564$ ). Although not causal, this relationship may highlight the importance of cortically directed treatment options, such as visual or auditory feedback during strength and movement training, when attempting to restore functional symmetry during the terminal phases of rehabilitation after ACLR.

## Functional implications of symmetry

Return to optimal and symmetrical muscle function is a common clinical goal that is important for restoration of lower extremity movement quality, functional performance, and improvement in patient outcomes, as well as for reduction of reinjury risk after ACLR.<sup>11,15-18</sup> Our current work focuses on the relationship between asymmetry in muscle function and movement quality and between asymmetry in muscle function and patient-reported function after return to physical activity in patients with a history of unilateral ACLR. This approach lets us investigate the source of potential dysfunction while better understanding its clinical manifestations to provide clinicians with guidance regarding the most effective evaluative and treatment techniques for patients experiencing asymmetry in quadriceps function following ACLR.

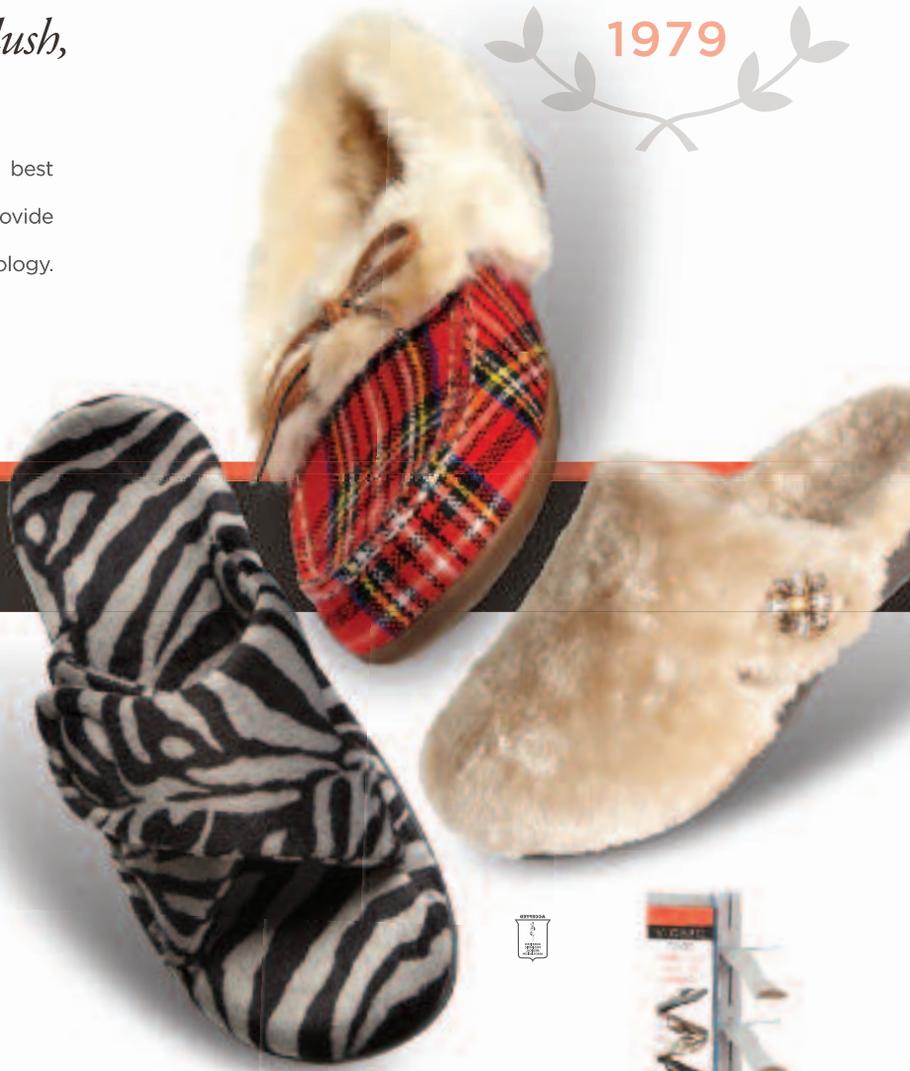
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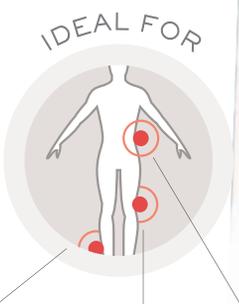
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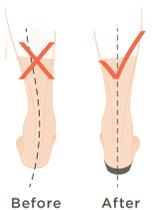


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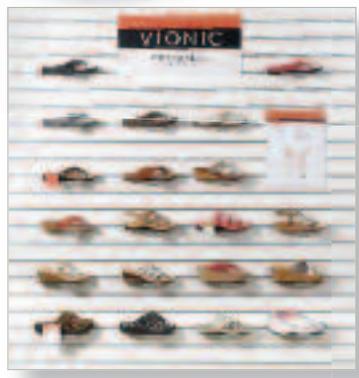


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## Symmetry and movement quality

Recently, we assessed the relationship between Landing Error Scoring System (LESS) score,<sup>19</sup> a validated assessment tool for identifying patients at high risk for ACL injury, and symmetry of quadriceps function in individuals with a history of ACLR.<sup>16</sup> Although our publication focused on the relationship between bilateral knee extension MVIC (maximum voluntary isometric contraction) torque and LESS score, a subsequent reanalysis that focused on symmetry of knee extension MVIC torque revealed some findings that of interest to clinicians.

In those with a history of ACLR, we found a moderate and negative relationship ( $\rho = -.584$ ) between knee extension MVIC torque and LESS score, indicating that those with better symmetry in quadriceps function also displayed fewer landing errors, which in turn suggests a lower risk of ACL injury (Figure 1). In addition, symmetry of quadriceps strength predicted 30.4% of the variance in LESS score, which establishes a relatively strong causal relationship between these variables. A number of other variables (eg, proprioception, dynamic balance, and fear of movement) undoubtedly contribute to landing errors or, more importantly, risk of ACL injury, but reestablishing symmetry in knee extension strength may be an important first step in improving patient's movement profiles.

Our findings are consistent with several other studies that have established a link between symmetry in quadriceps function and functional performance, which most commonly has been assessed using single-leg hopping distance.<sup>12-14,20</sup> Over the course of several studies, it has been shown that symmetry in knee extension strength is a significant predictor of functional performance and advantageous knee biomechanics during a hopping task.<sup>14,20</sup> In addition, improvement in quadriceps function symmetry over the course of recuperation from ACLR is associated with improvement in hop performance.<sup>3,21</sup> Although this is a rapidly expanding area of research, these findings are consistent with the approach of many clinicians, specifically the focus on improving a patient's lower extremity strength before attempting to retrain movement patterns during rehabilitation after ACLR.

## Symmetry and patient-reported outcomes

The importance of reestablishing quadriceps function and movement quality following ACLR is clear; however, patient-reported improvement in activities of daily living, knee-related function, and physical activity are more patient-centric outcome measures. In a recent study investigating whether symmetry of knee extension MVIC torque or quadriceps central activation ratio could predict patient-reported knee-related function, we found that near-full symmetry for either measure of quadriceps function was an adequate indicator of patient-reported knee-related function in those with a history of ACLR.<sup>15</sup> These findings were consistent with a limited number of previous studies that have investigated this topic in individuals with a history of ACLR.<sup>3,21,22</sup> Continued research on the impact of quadriceps function symmetry and lower extremity movement patterns on patient-reported function, as well as physical activity level, represents a natural next step in this field that has the potential to greatly impact the current approach to rehabilitation after ACLR.

## Limitations of symmetry as a tool

As with other clinical tools for physical assessment, there are limitations to the use of neuromuscular, biomechanical, or functional symmetry as standalone measures of lower extremity function following ACLR. The major assumption when using complete or near-complete symmetry as an indicator of optimal lower extremity function or patient readiness for a return to physical activity following ACLR is that the contralateral limb or healthy limb is indicative of ideal muscle function, movement quality, or functional performance.

Although it is possible that the contralateral limb is the model of optimal comprehensive lower extremity function, ACLR has been shown to be associated with reduced contralateral quadriceps strength and activation<sup>7,8,23</sup> as well as altered knee biomechanics during landing in the contralateral limb, despite no injury to the joint or surrounding muscle tissue.<sup>11</sup> This "crossover" effect has been shown in a number of clinical populations with a unilateral injury or disease process.<sup>24-26</sup>

In addition, up to 15% of patients with an ACL injury may have experienced an ACL injury or injury to another structure within the contralateral limb that required surgical intervention.<sup>27</sup> This may not immediately invalidate a measure of symmetry; however, additional consideration and concern should be taken when attempting to make comparisons between limbs. In this subgroup, it may be more valuable to focus on maintaining symmetry while facilitating bilateral functional improvements instead of focusing exclusively on reestablishing between-limb symmetry.

## Clinical take-home messages

Quantification and prospective tracking of symmetry and asymmetry of quadriceps muscle function following ACLR can provide clinicians and patients with important information regarding the effectiveness of treatment throughout rehabilitation. Using limb symmetry indices may enable clinicians to better quantify and compare persistent alterations in muscle function, movement patterns, and functional performance following ACLR. In addition, recent evidence supports a relationship between neuromuscular symmetry and both biomechanical and functional symmetry, which may help guide clinicians toward targets for early clinical intervention during the rehabilitation process.

The link between symmetry in quadriceps muscle function and movement quality, as well as the link between quadriceps muscle function symmetry and patient-reported function, have been established throughout the literature and should be considered when designing and implementing rehabilitation protocols and return-to-play guidelines. Despite the consistency of these findings, it's important to account for limitations associated with assessments of asymmetry, including the impact of ACLR on the uninvolved limb, when integrating these estimates into the clinical decision-making process. 

*Christopher Kuenze, PhD, ATC, is assistant professor in the Department of Kinesiology at Michigan State University in East Lansing, and the director of its Sports Injury Research Laboratory. Adam Kelly, MS, ATC, is a doctoral student in the Department of Kinesiology at Michigan State University and a research assistant in the Sports Injury Research Laboratory.*

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## Intermittent claudication: Next-generation therapy

Given that existing therapies for intermittent claudication are not appropriate for all patients, researchers are working to develop new therapies focused on improving patients' ability to compensate for a vascular occlusion by expanding collateral artery pathways.

By Steven J. Miller, PhD; A. George Akingba, MD, PhD; and Joseph L. Unthank, PhD

The progression of atherosclerosis may lead to stroke and the development of coronary heart disease, peripheral arterial disease (PAD), or both. PAD has been identified as a global health issue, impacting 202 million people worldwide<sup>1,2</sup> and approximately eight million in the US.<sup>3</sup> Of the US PAD population, 10% to 12% eventually experience intermittent claudication as a result of arterial insufficiency or inadequate blood perfusion in the leg muscles.<sup>4,5</sup> Approximately 20% to 30% of claudicants with subcritical limb ischemia progress to critical limb ischemia within 10 years of diagnosis, and the percentage is even higher if diabetes is present.<sup>6</sup>

As a result of the large population affected and the impact on lifestyle, new therapies to treat PAD are needed urgently.<sup>7,8</sup> While surgery<sup>9</sup> and exercise<sup>10</sup> may be appropriate and highly efficacious for certain subsets of patients experiencing claudication, these approaches are not suitable in all cases. Experimental therapies using stem or progenitor cells are being investigated, but overall efficacy remains unclear in clinical trial results to date,<sup>11</sup> and it will likely be several years before cell therapy becomes a viable treatment.

An effective pharmacological approach to the treatment of claudicants thus would be desirable, and a recent study<sup>12</sup> suggests novel pharmacological approaches may provide significant benefit. However, the only pharmaceutical agents currently approved by the US Food and Drug Administration to treat intermittent claudication are the phosphodiesterase inhibitors pentoxifylline and cilostazol,<sup>8</sup> and these drugs have been shown to provide only minimal improvement for claudicants in terms of maximal treadmill walking distance.<sup>13</sup> In addition, they are expensive, have multiple side effects, and are contraindicated in patients with congestive heart failure.

### Collateral opportunities

A natural compensation for PAD-related vascular occlusions and resultant claudication is expansion of preexisting arterial pathways, known as collateral arteries, which bypass an occlusion and provide

Preclinical and clinical evidence suggests targeting Nox-derived reactive oxygen species is a viable strategy for prevention and treatment of intermittent claudication.



increased blood flow to peripheral tissues, especially during periods of increased metabolic demand. Although younger individuals have a high capacity to compensate for arterial occlusion through collateralization, compensation in those with atherosclerotic risk factors and comorbidities is greatly diminished.<sup>14</sup> More research is needed to identify the mechanisms responsible for the impairment of the natural outward expansion of collateral arteries.

As reviewed by Ziegler et al,<sup>14</sup> it has been demonstrated in mul-

tipule species that, following an acute femoral artery occlusion, the majority (about 70%) of the total vascular resistance resides in the collateral arteries rather than the distal microcirculation. Although the formation of new capillaries (angiogenesis) and arterioles in muscle tissue may contribute to correcting a perfusion deficit, overall increased flow to the extremities is largely dependent on the small arteries that form the collateral pathways. Thus, strategies to promote collateral formation should have a greater impact on intermittent claudication patients than therapies affecting only angiogenesis.

Cardiovascular risk factors associated with development of PAD and intermittent claudication include aging, hypertension, and diabetes or metabolic syndrome. These risk factors are associated with vascular dysfunction and impair the process of collateral development in both humans and animals.<sup>15-19</sup> A common denominator for all these risk factors is the presence of elevated reactive oxygen species (ROS), which have been shown to be present in PAD patients<sup>20-22</sup> and to inhibit collateral formation in animals.<sup>23-25</sup> Thus, strategies for reducing production of or scavenging of excess ROS would be expected to promote collateral formation in patients with PAD. Indeed, results from trials using agents capable of altering vascular redox status (equivalent to ROS level) have shown significant impact on maximal walking distance in claudicants.<sup>12,26,27</sup> Our research to date has focused on using preclinical models with cardiovascular risk factors to test the concept of altering vascular redox status to facilitate collateral growth.

## Insight from preclinical models

There are many preclinical models for the study of collateral development in the context of arterial insufficiency.<sup>28</sup> Our laboratory has

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utilized two different rodent models to study the role of ROS in the regulation of primary collateral formation.

One model uses serial ligations in the rat mesenteric vasculature to elevate blood flow in selected arteries and thus simulate formation of a collateral pathway.<sup>25,29</sup> This model has the advantage of a readily accessible vasculature for repeated diameter measurements in situ in the same arteries, the ability to make hemodynamic measurements of flow and shear stress, and sufficient tissue to enable molecular studies of gene regulation and expression.

The second model is a mouse distal femoral artery ligation model that results in the gracilis arteries forming the primary collateral pathway.<sup>30</sup> This mouse model is relevant to most claudication patients because it represents the most common site of focal occlusion, and also has the advantage of allowing the use of genetically modified animals to address mechanistic questions. The majority of studies using mouse femoral ligation have used a more severe model utilizing arterial ligation/excision techniques to focus on critical limb ischemia, and these models have been used primarily to assess hindlimb tissue perfusion and angiogenesis rather than remodeling of the resistance vessels that comprise the primary collateral pathways.

We have used the rat mesenteric and mouse femoral ligation models to investigate mechanisms regulating the promotion and impairment of primary collateral artery growth as well as agents to reverse collateral growth impairment in the presence of cardiovascular risk factors.

A recent study from our group investigated the role of the enzyme complex NADPH oxidase (nicotinamide adenine dinucleotide phosphate oxidase, or Nox) as an ROS source in physiological

collateral growth.<sup>31</sup> Vascular Nox exists as three isoforms in the rodent, Nox1, Nox2, and Nox4, along with multiple associated subunits.<sup>32</sup> Humans possess an additional isoform, Nox5.<sup>32</sup>

While Nox is thought to be the major source of vascular ROS, the roles of the various forms of Nox in different cell and tissue types and in various pathological conditions is not well delineated. ROS-mediated signaling is known to be essential for normal physiological vascular function,<sup>33-35</sup> and the results from our work using both of the previously described models confirm that ROS are required for primary collateral artery development.<sup>31</sup> These results, based on specific inhibitors of activity and expression, along with genetic ablation, also indicate that the NADPH oxidase Nox2 isoform is a primary source for the redox signaling associated with successful flow-mediated remodeling in healthy young animals.

## Collateral flow modeling

We also have examined the role for ROS during periods of acute increases in collateral flow, which occur following an occlusion and precede the outward remodeling required for collateral formation. These experiments used acute vascular clamping and measurement of perivascular hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) concentrations with microelectrodes to study regulation of H<sub>2</sub>O<sub>2</sub> that occurred with elevated flow in young, aged, and hypertensive rats. The results demonstrated that 1) perivascular H<sub>2</sub>O<sub>2</sub> concentrations are higher in both aged and spontaneously hypertensive rats (SHR) than in young, normotensive rats; 2) H<sub>2</sub>O<sub>2</sub> concentrations increase with elevated flow; and 3) Nox2 activation was responsible for its production.<sup>36,37</sup>

*Continued on page 58*

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Continued from page 57

These results with acutely elevated flow likely parallel what occurs during early stages of collateral growth, and indeed, we have demonstrated that administration of antioxidants concurrent with creation of a mesenteric ligation model reverse impairment in both aging rats<sup>24</sup> and SHR<sup>25</sup> and also in diet-induced obese mice using the femoral ligation model.<sup>38</sup> Results from these studies also have demonstrated that antioxidants administered up to a week after establishment of vessel occlusion in an aged animal could reverse impaired collateral growth by promoting flow-mediated remodeling.<sup>24</sup> This methodology is analogous to the clinical situation in which therapies are initiated well after arterial insufficiency has been established. Evidence for a role of elevated Nox2 activation in collateral development is provided by a recent study in our lab indicating that activation of Nox2 by the p47<sup>phox</sup> subunit is an important factor involved in collateral growth impairment in the context of diet-induced obesity.<sup>38</sup>

Although there is much preclinical evidence for a role of Nox-mediated oxidant stress in impaired collateral development, there is a lack of knowledge in the area of the signaling pathways, molecules, and mechanisms involved. To begin to address this issue, we conducted a study using cDNA microarrays to examine global gene expression changes in mesenteric normal flow and high-flow collateral arteries of SHR compared with normotensive rats.<sup>39</sup> An important finding was that major differences in collateral artery gene expression existed between groups; only 6% of genes had similar expression. These differences included mechano-sensitive, redox-regulated transcription regulators, which regulate expression of multiple proteins involved in vascular remodeling.

We determined that at least one of the transcription regulators was activated in endothelial cells of arteries in the normotensive rats, but not in the SHR. Interestingly, administration of the antioxidant apocynin stimulated this activation in the SHR, and we have previously shown that apocynin also reverses the collateral growth impairment in SHR.<sup>25</sup> Other experiments have shown that the angiotensin type 1 receptor is involved in signaling necessary for collateral growth.<sup>39</sup> These results suggest that collateral growth impairment results from an abnormality in a regulatory mechanism occurring between initial signal transduction and eventual gene transcription, and support redox-dependent modulation of transcription factors as a potential mechanism.

Our ongoing work in aged rats (unpublished data) indicates Nox2 inhibition or catalase administration reverses collateral growth impairment, implicating Nox2-derived H<sub>2</sub>O<sub>2</sub> as an important ROS. Recent studies have shown that Nox2 activation and mitochondrial dysfunction both contribute to cellular oxidant stress, and the pathways involved in these events may interact.<sup>40,41</sup> Future studies will focus on the involvement of mitochondrial oxidant stress and interactions with Nox2 as an important regulator of impaired collateral artery development. Other recent work in our laboratory has focused on developing a new technique using preclinical rodent models to allow assessment of the role of the collateral circulation in increased limb perfusion during periods of muscle activity. This type of model should allow us to better evaluate the effects of therapeutic agents designed to ameliorate subcritical limb ischemia.

## Clinical relevance

Although much preclinical evidence exists for a role of oxidant stress in cardiovascular disease, trials in humans with various antioxidants have been largely unsuccessful. This can perhaps be

explained by issues related to use of inappropriate or ineffective agents, suboptimal doses, or failure to screen patients for the presence of oxidant stress,<sup>42</sup> among others.

A recent randomized placebo-controlled trial of 33 claudication patients (eight women, mean age 64.6 years) demonstrated that the angiotensin-converting enzyme (ACE) inhibitor ramipril was effective in increasing maximal walking distances.<sup>12</sup> Compared with placebo, ramipril improved maximum treadmill walking distance by an adjusted mean of 131 m (62-199 m) ( $p = .001$ ), treadmill intermittent claudication distance by 122 m (56-188 m) ( $p = .001$ ), and patient-reported walking distance by 159 m (66-313 m) ( $p = .043$ ). Measurements of pulse wave velocity indicated that a likely explanation for the improvement was a decrease in arterial stiffness. Research has shown that impaired arterial elasticity in humans is associated with oxidative stress.<sup>43</sup>

An additional meta-analysis of six randomized controlled trials with 821 claudicants has indicated that ACE inhibitors in general are effective in increasing maximal walking distance, and the effect is due at least in part to an improvement in endothelial function.<sup>27</sup> Specifically, the meta-analysis found that treatment with ACE inhibitors improved maximum walking distance by a mean difference of 120.8 m (2.95-238.68 m) ( $p = .04$ ) and pain-free walking distance by 74.87 m (25.24-124.5 m) ( $p = .003$ ) compared with placebo.

Nox2, a primary source of vascular oxidant stress, is stimulated by angiotensin II;<sup>41</sup> thus, ACE inhibitors may function at least in part by suppressing activity of Nox2, thereby improving endothelial function. PAD patients have elevated levels of circulating oxidant stress markers,<sup>20</sup> and this includes a soluble form of Nox2.<sup>21</sup> It is possible that agents like ramipril that prevent formation of ROS may be more effective than agents that scavenge ROS,<sup>42</sup> which describes many antioxidants tried to date in clinical trials. Use of Nox inhibitors also may have the additional benefit of suppressing development of atherosclerosis,<sup>44</sup> thereby potentially preventing onset of PAD-mediated claudication.

Certain problems will need to be addressed before redox modulation could be a viable therapy. Because Nox isoform expression and activity varies by cell and tissue type, it will be important to develop targeted therapies. In addition, there is the possibility of antioxidant agents interfering with physiological processes requiring redox signaling, such as flow-mediated dilation.<sup>34</sup> Nevertheless, evidence from clinical trials, taken together with the preclinical evidence, suggests targeting Nox-derived ROS is a viable strategy for prevention and treatment of intermittent claudication, and perhaps even critical limb ischemia. 

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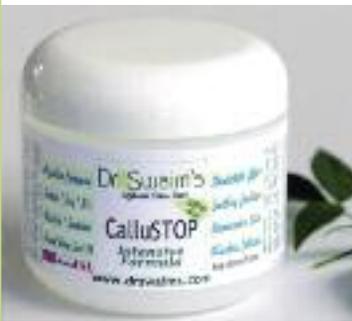
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## CMS stays prosthetic coverage draft; AOPA calls the decision a 'partial win'

The White House announced on November 2 that the Centers for Medicare & Medicaid Services (CMS) will not finalize a controversial draft policy concerning coverage determinations for lower limb prostheses.

The American Orthotic & Prosthetic Association (AOPA) in a press release the same day termed the response a "partial win," noting the draft policy hadn't been rescinded and citing concerns about public stakeholders' absence from the CMS-proposed workgroup that in 2016 will develop an evidence-based consensus statement on best practices in lower limb prosthetic care.

The multidisciplinary Lower Limb Prostheses Interagency Workgroup will be composed of "clinicians, researchers, and policy specialists from different federal agencies," according to the

announcement on the We the People website.

"We recognize and believe it is a positive step that the draft LCD [Local Coverage Determination] will not be implemented at this time. However, we continue to believe that the draft LCD should be rescinded by the Medicare Contractors and that CMS should provide patient and provider stakeholders with a meaningful role in the development of future coverage policies for lower limb prostheses," AOPA said in its press release.

The amputee community and O&P organizations have led a vocal battle against the lower limb prostheses LCD since it was proposed on July 16, reporting that current scientific evidence didn't support the proposed changes, which they said threatened to return amputees to 1970s care. 

## Judges weigh murder charge for Pistorius

Five South African judges are considering the fate of Oscar Pistorius after a November 3 hearing in the Supreme Court of Appeal in Bloemfontein.

Prosecutors for the state claimed Pistorius should have been convicted of murder rather than culpable homicide for killing Reeva Steenkamp in February 2013.

The defense continued to maintain the double amputee and

former athlete—who was released October 19 from prison to house arrest after serving one year of his five-year term—feared for his life as he fired a gun through a closed bathroom door at a person he thought was an intruder.

If the panel, which is expected to announce its verdict by the end of year, finds Pistorius guilty of murder, he could return to prison for a minimum of 15 years. 

## AMP1 team showcases stand-up skills

AMP1, the stand-up amputee basketball team sponsored by Irvine, CA-based Freedom Innovations, showcased its skills in the October "Duel In The Desert" event in Phoenix, AZ. A red AMP1 team played its blue counterpart, with the blue team winning the tournament championship game 21-9. Some AMP1 team members

wore the Freedom Innovations Renegade Foot and transfemoral amputee players used the company's Plié MPC Knee.

The event, held at the accessible sports facility Ability360 Sports and Fitness Center, also featured adaptive sports teams competing in wheelchair basketball, rugby, and soccer. 

## Össur hosts Boston bombing survivors

Boston Marathon bombing survivors Patrick Downes and Jessica Kensky in September visited Össur's global headquarters in Reykjavik, Iceland, to discuss their experiences as recent amputees and to learn about innovations in prosthetic limbs.

In April 2013, then-newlyweds Downes and Kensky were spectators standing near the marathon's finish line. Both lost lower limbs as a result of the explosion and wear Össur prostheses. Downes is a below knee amputee, and Kensky recently became a bilateral below knee amputee after undergoing a

number of surgeries.

During their visit, the couple gave feedback about their Össur devices to the company's R&D team and previewed next-generation prosthetic innovations.

Robert Barber, US ambassador to Iceland and long-time family friend of Downes, and Mike Corcoran, CPO, who heads the Medical Center Orthotics & Prosthetics in Silver Spring, MD, accompanied the couple on their tour. Corcoran played a central role in Kensky's recovery while she received care at Walter Reed National Military Medical Center earlier this year. 

## AAOS clarifies guidance for ACL injuries

The Rosemont, IL-based American Academy of Orthopaedic Surgeons (AAOS) in October released a new appropriate use guideline for anterior cruciate ligament (ACL) injury to clarify recommendations from its 2014 ACL injury guidelines.

The AAOS 2014 Clinical Practice Guideline, "Management of Anterior Cruciate Ligament Injuries" recommended that reconstructive surgery occur within five months of ACL injury to protect the knee joint and that, in young adults aged 18 to 35 years, autografts are

preferable to allografts for ACL reconstructions.

The new appropriate use guideline provides more specific guidance based on a patient's various indications, including age, activity level, presence of advanced arthritis, and status of the ACL tear. The guidelines recommend specific next steps and procedures for optimal recovery.

The AAOS also offers ACL rehabilitation and return-to-play checklists. Get the guidelines and checklists and link to a smartphone app at [orthoguidelines.org/auc](http://orthoguidelines.org/auc). 

## Kingetics awarded for advanced materials

The American Composite Manufacturing Association and the Society for the Advancement of Material and Process Engineering honored Kingetics for its creativity with application of advanced materials at the Composites and Advanced Materials Expo (CAMX) in October in Dallas, TX.

The Arlington, VA-based association and Covina, CA-based society gave Kingetics the Most Creative Application of Advanced Composite Materials honor for the integration of the Kihei, HI-based company's orthotic sys-

tem into an improved combat boot for military use.

The system increases the boot's puncture, blast, and fire resistance with ballistic-resistant materials; increases energy efficiency of gait through a spring lever orthotic and prosthetic mechanism; increases stability of gait and stance with the applied physics of levers; and decreases the weight of the boot by 25% compared with current US Army-mandated issue polyurethane foam boots, according to a Kingetics release. 

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## OHI acquires custom orthotic lab Footbön

Ronkonkoma, NY-based Orthotic Holdings (OHI) in October acquired the custom foot orthotic laboratory Footbön. Paul Langer, who founded Huntington, NY-based Footbön in 2009, has joined OHI's Langer Biomechanics as vice president of operations. His father, Sheldon Langer, cofounded Langer Biomechanics in 1969.

Also in October, OHI and Santa Clara-based Sensoria debuted an internet-connected version of the Moore Balance

Brace at Healthcare 2.0, a global healthcare technology conference in Santa Clara. The smart update of the brace, which helps reduce fall risk in older adults by improving balance and stability, allows clinicians to monitor patients' adherence to device use, activity levels, and gait parameters.

OHI's brands also include Apex Foot Health, Arizona AFO, Australian Orthotic Group, Ped-Align, The Orthotic Group, and SafeStep. 

## Dates set for World Congress of Podiatry

The International Federation of Podiatrists and the Canadian Podiatric Medical Association in October announced that the 2016 World Congress of Podiatry is scheduled for May 26-28

in Montreal, Canada.

Podiatrists, physicians, students, other foot health practitioners, and exhibitors can get more information about the conference at [fipworldcongress.org](http://fipworldcongress.org). 

## Cadence Kickstart studied for stroke rehab

Seattle, WA-based Cadence Biomedical in October announced a National Institutes of Health-funded research collaboration with the University of Nebraska-Omaha (UNO) to study stroke survivors' ability to adapt and improve motor skills using the company's neurorehabilitation Kickstart device.

The research is investigating ways in which using the Kickstart in virtual reality environments can create lasting motor adap-

tations for stroke survivors, said Mukul Mukherjee, PhD, assistant professor of health, physical education and recreation at UNO and study principal investigator.

"Kickstart represents a technology that has great potential to enhance such motor adaptations at a relatively low cost," he said. "We hope to enhance gait adaptations that will help to improve therapeutic rehabilitation for stroke survivors." 

## Tamarack wins business award for textiles

Minneapolis-based *Minnesota Business Magazine* in September awarded Tamarack Habilitation Technologies its Minnesota Manufacturing Award in the New Products: Textiles category.

Blaine, MN-based Tamarack

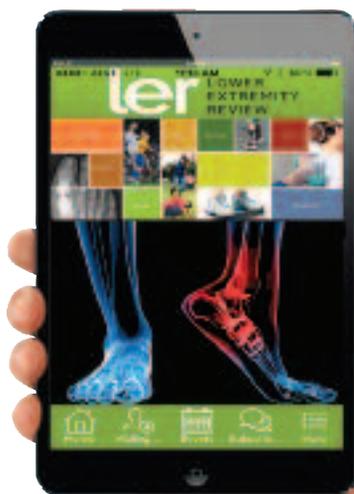
won for its GlideWear Shear Protection line that features the company's dual-layer friction management fabric technology for shear protection in its socks, prosthetic liners, and other products. 

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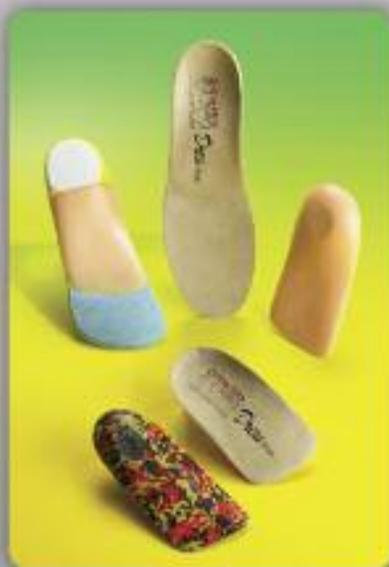
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