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July 16 / volume 8 / number 7

**7-YEAR**  
ANNIVERSARY ISSUE

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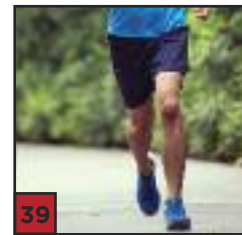
Study findings regarding strengthening interventions in runners with patellofemoral pain syndrome have been inconsistent, perhaps because specific subgroups are more responsive than others. Preliminary research suggests high school runners may make up one such subgroup.

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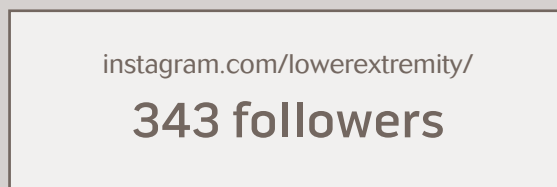
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When we launched *LER* in 2009, it was because I kept hearing that the market needed something different. I did my best to assemble the best team to deliver the best content for you. Seven years later, *LER*

is still going strong and our momentum keeps building. There are definitely times when I need to pinch myself.

Listening to the needs of our readers has always been key to the success of *LER*, and it has also been an important factor in our growth. We are always considering ideas for expanding in different directions under the broad category of lower extremity care, but to maintain quality we know we need to be very selective about which of those directions we end up exploring. Since 2014, we have launched two new quarterly magazines, *LER: Foot Health* and *LER: Pediatrics*. These additional pages of focused, evidence-based content—as well as a more targeted advertising base—are intended to help you as lower extremity clinicians treat your patients more effectively, stay informed about the most current research, and grow your practice. Your support and dedication have made both of these publications a success.

To further support the community and consistently provide you with easy access to our articles and references, we have launched a new dedicated website for each of these quarterly publications. [LERfoothealth.com](http://LERfoothealth.com) and [LERpediatrics.com](http://LERpediatrics.com) are up and running, so please check them out and let us know what you think. We are always listening.

## Publisher's memo: Our ears are open

These exciting developments could not have happened without the contributions of two key groups of people. I want to acknowledge the *LER* editorial team for continuing to provide content that is so timely and on point. This excellent content is why our readers continue to be so engaged in the growing *LER* platform. I also want to acknowledge our supportive advertising community, which consistently offers innovative products to help you in your practice. Without them, we would not be able to provide you with the quality information you've come to expect from *LER*. When I hear from a company that a customer said, "I saw your ad in *LER*," it means a lot to me, and I thank you for that!

Looking for new opportunities in business can be a challenge, and one way to meet that challenge is by opening our ears.

We all know that businesses can become complacent. This is definitely not the case with the *LER* team. Looking for new opportunities in business can be a challenge, and one way to meet that challenge is by opening our ears. To best serve the lower extremity market, we need to consistently listen to determine where we can delve deeper. I encourage ideas and input from anyone affiliated with *LER* in any way—a team member, freelance writer, friend, family member, reader, or advertiser could come up with the next good idea for us to explore. So please continue to use your voice and express your ideas. Feel free to reach out to me directly at [rich@lermagazine.com](mailto:rich@lermagazine.com). I would love to hear what you have to say. Who knows—your suggestion could be the inspiration for our next quarterly magazine!

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Patellofemoral pain's subgroup situation just got a lot more interesting, thanks to study findings presented in June at the annual meeting of the National Athletic Trainers Association in Baltimore, MD.

Researchers and clinicians who treat patients with patellofemoral pain (PFP) have long been frustrated

by the fact that interventions—specifically designed based on the existing literature on PFP risk factors—seem to be consistently effective in some patients, but not all. This pattern suggests that, even in a PFP population that at first appears homogeneous, there are probably subgroups of patients who differ from each other in ways that affect their response to the interventions that have been tested thus far.

The search for PFP subgroups has been an ongoing theme in the medical literature and in the discussions at the four International PFP Research Retreats (see “Conference coverage: 4th PFP research retreat,” January 2016, page 29). In this issue, Lace Luedke, PT, DPT, PhD, nicely summarizes the variable findings in the literature related to lower extremity strengthening in runners with PFP, and reviews her group's work suggesting that hip and knee weakness in high school cross-country runners is predictive of PFP risk (see “Lower extremity strength and injury risk in runners,” page 39). This, in turn, suggests that high school cross-country runners may constitute a subgroup that is more likely to benefit from hip and knee strengthening.

Luedke notes, however, that strength assessed isometrically—as most PFP studies have done—may not correlate strongly with muscular control or kinematics, and therefore may not be the best variable on which to base subgroup-specific interventions. Intuitively, this makes sense: Strength typically is not as clinically relevant as the ability to use it.

## out on a limb: PFP pathfinding

That's where the research presented at NATA comes in. Investigators from Brigham Young University in Provo, UT, analyzed the gait of 30 young adults with PFP. All participants had similar self-reported levels of pain, activity, and kinesiophobia, but half were defined as being “quadriceps functional” or “quadriceps deficient” based on central activation ratio (CAR). And as it turned out, the between-group differences in quadriceps function were associated with differences in gait mechanics, including knee flexion angle, knee extension torque, and vertical ground reaction force.

**New findings suggest functional strength may be more useful than isometric strength for defining patellofemoral pain subgroups.**

This study has two important take-home messages. The first is that self-reported pain level should not be the sole determinant of any type of PFP intervention, since individuals with similar self-reported pain scores can differ considerably in terms of quadriceps function and gait mechanics. The second is that, as many have suspected, a “functional strength” measure like CAR may be better than isometric strength for defining PFP subgroups and developing targeted interventions.

Of course, such interventions have yet to be developed and tested. And, given the difficulty of testing for CAR and other activation-based measures outside of a laboratory, researchers will also want to look for correlations with variables that are easier to assess clinically. But it seems likely that this line of investigation will take the PFP subgroup discussion in new—and, hopefully, rewarding—directions.

Jordana Bieze Foster, *Editor*



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## Joint injury's lifelong impact

### Data suggest comorbidity implications

By Jordana Bieze Foster

A history of knee or ankle injury is associated with an increased risk of medical issues—and not just those related to joint health—in middle age and later decades of life, according to research presented in June at the annual meeting of the National Athletic Trainers Association (NATA) in Baltimore, MD.

Not only are people older than 40 years who report a history of knee or ankle injury more likely than their uninjured counterparts to have osteoarthritis (OA), they are also more likely to have a cardiovascular or respiratory disease, the researchers found.

The findings underscore the long-term importance of prevention and early intervention with regard to knee and ankle injuries, said study author Phillip Gribble, PhD, ATC, an associate professor and director of the Division of Athletic Training at the University of


## Specialization, participation volume contribute to youth athlete injury risk

Sport specialization and high volumes of sports participation are significantly associated with the risk of injuries—and overuse injuries in particular—in youth athletes, according to research from the University of Wisconsin-Madison.

Investigators surveyed 2011 youth athletes (mean age, 13.7 years; 989 girls) about their sports participation patterns and injury history. More than one third (37.5%) of the athletes were highly specialized (they had played one sport for more than eight months of the year, considered their primary sport most important, and had quit other sports to focus on a primary sport). Girls were more likely to be highly specialized

than boys (41% vs 34%).

Highly specialized youth athletes were 1.59 times more likely to report any injury and 1.45 times more likely to report an overuse injury than their less-specialized counterparts. Athletes who played one sport for more than eight months of the year were 1.85 times more likely to report any injury and 1.6 times more likely to report an overuse injury.

The findings were presented in June at the NATA annual meeting in Baltimore, MD. 

Source:

Post EG, Riekema JW, Trigsted SM, et al. The association of sport specialization and training volume with previous overuse injury in youth athletes participating in youth sports tournaments. *J Athl Train* 2016;51(6 Suppl): S145.



Kentucky in Lexington.

"Once these patients leave our care and get into their forties and fifties, it's not such a simple problem," Gribble said. "We need to do a better job with prevention and treatment."

Investigators from the University of Kentucky and the University

*Continued on page 16*


## Upper body position during landing affects kinetics in basketball players

In basketball players, upper extremity ball handling positions affect lower extremity kinetics during landing and should be considered when designing injury prevention and rehabilitation protocols, according to research from George Mason University in Fairfax, VA.

Investigators analyzed the lower extremity biomechanics of 30 healthy young adults as they performed drop landings under four conditions: with hands on hips, holding a basketball at chest level with the arms crossed, at chest level with the arms extended, or with the ball raised overhead.

Landing while holding a ball with the arms across the chest was associated with significantly

lower knee flexion moments than when the ball was overhead or when the hands were on the hips.

This suggests coaching basketball players to land from a rebound, for example, with the ball held close to the chest may decrease the risk of knee injury, according to Jatin P. Ambegaonkar, PhD, codirector of the university's Sports Medicine Assessment Research and Testing Laboratory, who presented the findings in June at the NATA annual meeting in Baltimore, MD. 

Source:

Ambegaonkar JP, Oladipo E, Caswell SV, et al. Changing ball-handling positions affects lower extremity moments during landing. *J Athl Train* 2016;51(6 Suppl): S194.

# in the moment: sports medicine

Continued from page 15

of North Carolina at Charlotte (UNCC) surveyed more than 3500 adults recruited through the online service researchmatch.org, who ranged in age from 18 to 80 years. Of those, 1843 reported a history of ankle injury, 647 reported a history of knee injury requiring surgery, and 1046 reported a history of both ankle and knee injuries.

Rates of ankle OA were higher for survey respondents with a history of ankle injury (9.4%) than their uninjured counterparts (1.8%), and rates of knee OA were higher for those with a history of knee surgery (54.4%) than those with no knee injury (5.1%). Participants in their 40s and older were significantly more likely to have ankle OA if they also had a history of ankle injury than if

they didn't; similarly, individuals in middle age and older were also more likely to have knee OA if they also had a history of knee surgery or knee injury.


More surprising were the associations found between knee or ankle injury and cardiovascular or respiratory comorbidities. Survey respondents were more likely to report a cardiorespiratory condition if they had a history of ankle injury (30.9%) than if they didn't (24.5%), and if they had a history of knee surgery (39.3%) than no history of knee injury (23.5%). The age distribution patterns for comorbidities were similar to the patterns for OA, with group differences emerging between ages 40 and 59 years.

"If we're going to intervene in these patients, not only do

we need to be optimizing joint health, we also need to be optimizing overall general health," said Abbey Thomas, PhD, ATC, an assistant professor in the Department of Kinesiology at UNCC, who presented the knee injury findings at the NATA meeting.

In study participants with a history of injuries to both the knee and ankle, rates of ankle OA (67.9%) and knee OA (58.5%) were higher than in those with a history of either injury alone. Interestingly, a history of both types of injuries was associated with OA in even younger age groups—starting in the 30s—than a history of either knee or ankle injury alone. A higher percentage of survey respondents with a history of both knee and ankle injuries also reported cardiorespiratory

comorbidities than those with knee injury (26.6%) or ankle injury (27.5%) alone.

"We're seeing these comorbidities across the board, no matter the injury or combination of injuries," said Steven Pfeiffer, a graduate student in the UNCC Biodynamics Research Lab, who presented the combined-injury findings at the NATA meeting. 

Sources:

Gribble PA, Pfeiffer S, Turner M, et al. Long term consequences of ankle injury in the general population. *J Athl Train* 2016;51(6 Suppl): S20.

Thomas AC, Pfeiffer S, Turner M, et al. Osteoarthritis and comorbidity prevalence among patients with a history of knee surgery. *J Athl Train* 2016;51(6 Suppl): S20-S21.

Pfeiffer S, Turner M, Gribble PA, et al. Osteoarthritis and comorbidity prevalence among patients with a history of knee and ankle injuries. *J Athl Train* 2016;51(6 Suppl): S21.



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## Analyzing adherence

### Balance predicts off-loading device use

By Larry Hand

Postural instability in patients with diabetic foot ulcers is a strong predictor of poor adherence to off-loading treatment with removable devices, according to a new multicenter study in which off-loading adherence was, in turn, a strong predictor of wound healing.

"The off-loading devices would amplify the instability—hence the tendency to decrease adherence," first author Ryan T. Crews, MS, clinical research scientist and operations manager at Rosalind Franklin University's Center for Lower Extremity Ambulatory Research in North Chicago, IL, told *LER* by email.

In the same study, published in June by *Diabetes Care*, researchers found that more severe ulcer at baseline, more severe neuropathy, and greater self-reported foot pain were associated with better adherence to treatment.

"In this case, more severe wounds were associated with greater

## Gait differentiates healthy and diabetic controls from patients with foot ulcers

Gait mechanics in patients with diabetic foot ulcers differ from those of both healthy controls and patients with diabetes who have no history of foot ulcer, according to research from James Cook University in Queensland, Australia.

Investigators analyzed kinematic, kinetic, and spatiotemporal gait parameters in 21 people with diabetes-related neuropathic plantar foot ulcers, 69 "diabetes controls" (people with diabetes but no history of foot ulcer), and 56 healthy controls as they walked at a self-selected pace along a 10-m walkway embedded with force plates.

Compared with both control groups, the patients with diabetic foot ulcers demonstrated

significantly less plantar flexion, knee flexion, and pelvic obliquity. The group with foot ulcers also had significantly greater range of anterior-posterior ground reaction force, greater total vertical ground reaction force, slower walking speed, and smaller step length than controls.

The findings, published in late June by *Clinical Biomechanics*, are part of the Townsville Diabetes Foot Ulcer Study, which will continue to follow the two groups of patients with diabetes for six months. *ler*

—Jordana Bieze Foster

Source:

Fernando ME, Crowther RG, Lazzarini PA, et al. Gait parameters of people with diabetes-related neuropathic plantar foot ulcers. *Clin Biomech* 2016 June 29. *IEpub ahead of print*



adherence, which likely suggests that as patients became more concerned about the gravity of the situation, they became more compliant," Crews added.

Crews and colleagues prospectively assessed 79 patients with type 2 diabetes and plantar diabetic foot ulcers—46 in the UK and 33 in the US—who wore removable off-loading devices for six weeks.

They collected patient-reported data at baseline, then followed a standardized foot ulcer management protocol involving regular,

*Continued on page 18*

## MRI scan prior to first ray amputation not associated with reamputation risk

Obtaining an initial magnetic resonance imaging (MRI) scan prior to first ray amputation in patients with diabetes is significantly associated with a decrease in mortality rate but not reamputation rate, according to research from Staten Island, NY.

Investigators from Staten Island University Hospital retrospectively analyzed 368 patients with diabetes who had undergone a first ray amputation, and compared the rates of reamputation and mortality in those who had undergone an MRI scan prior to surgery and those who had not.

The researchers hypothesized that an initial MRI scan would improve surgical planning and postoperative care, reducing reamputation rates by allow-

ing clinicians to identify osteomyelitis and other pathologies that could negatively affect outcomes, as well as potential pressure points that could lead to subsequent ulcerations.

Although MRI was not associated with reamputation rate, the association with a decreased mortality rate suggests the MRI findings may have increased patient awareness of the need for diligent foot care, the authors wrote. The findings were published in June by *Diabetic Foot & Ankle*. *ler*

—Jordana Bieze Foster

Source:

Jbara M, Gokli A, Beshai S, et al. Does obtaining an initial magnetic resonance imaging decrease the reamputation rates in the diabetic foot? *Diabet Foot Ankle* 2016;7:31240.

# in the moment: diabetes

Continued from page 17

sharp surgical wound debridement, dressings, and off-loading ulcers. Ulcers were examined and photographed weekly.

They used a removable cast walker (RCW) as a default off-loading device, but clinicians were allowed to use other removable devices. Sixty-one of the 79 participants used a RCW. The researchers assessed off-loading adherence using a concealed activity monitor in the device and by asking participants to attach a second monitor to their hips during activity.

Overall, the group experienced a substantial reduction in mean wound size, from 230 mm<sup>2</sup> to 109 mm<sup>2</sup>. Nineteen (24%) participants achieved complete wound closure by the six-week visit. Patients averaged 6.7 hours a day of active movement and wore their off-loading

devices 59% of that time.

Better off-loading adherence was a predictor of decreased ulcer size by six weeks, as were smaller baseline ulcer size and UK location. There were no significant associations between off-loading adherence and ulcer-specific beliefs and emotional responses at baseline.

The researchers did not compare adherence differences between more stable and less stable patients. And they did not discuss design features of the RCW devices that may have contributed to postural instability specifically or adherence in general.

"We're presently researching design features that will make them more amenable to patients," Crews said.

The postural stability finding makes sense, Jaap van Netten,


PhD, scientific director at Diabetic Foot Australia in Queensland, told *LER* by email.

"Postural instability is enhanced when using a [cumbersome] device, so it is not surprising that adherence is lower in this group of patients, as they will experience more problems while wearing the device," van Netten said.

The study also underscores the complexity of patient adherence, which is important for clinicians to understand, he noted.

"Patients need to be motivated to adhere to the device," van Netten continued. "However, improving acceptance and motivation, and better communication, may all take some time in the early phases of treatment. Unfortunately, we see all too often that clinics are so packed that this time is not available,

even though this results in more time being spent in the long run. One way to improve adherence might be a greater investment in increasing patients' acceptance and motivation via person-centered communication early in treatment."

van Netten and colleagues described two patient-centered communication techniques to improve adherence to therapeutic footwear in an article published in June by *Prosthetics & Orthotics International*. 

Sources:

Crews RT, Shen B-J, Campbell L, et al. Role and determinants of adherence to off-loading in diabetic foot ulcer healing: a prospective investigation. *Diabetes Care* 2016 June 6. [Epub ahead of print]

van Netten JJ, Francis A, Morphet A, et al. Communication techniques for improved acceptance and adherence with therapeutic footwear. *Prosthet Orthot Int* 2016 June 8. [Epub ahead of print]



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# BLOOD FLOW RESTRICTION TRAINING:

The slow-flow movement is fast becoming rehab's hottest trend





Partially occluding blood flow to the limbs, in combination with low-load resistance exercise, appears to facilitate hypertrophy and strength gains in athletes and others while protecting the joints from damaging stresses.

By Cary Groner

When Johnny Owens, MPT, was chief of human performance optimization at the Center for the Intrepid at Brooks Army Medical Center in San Antonio, TX, from 2005–2015, soldiers were returning from overseas deployments with severely damaged legs due to bomb blasts and other combat injuries. Many had amputations, and for the rest, rehabilitation was challenging; of those who initially kept their limbs, roughly 15% had them amputated within five years.

“We had a problem trying to get those with really weak or damaged limbs to gain strength because they couldn’t tolerate heavy loads,” Owens said.

To help them regain capabilities, Army researchers developed a prosthetic partial exoskeleton,<sup>1</sup> but even this futuristic device required quadriceps strength beyond the capabilities of many patients.

Owens heard about a crazy-sounding approach pioneered in the 1980s by Japanese researchers, including Yoshiaki Sato, MD, PhD, and Takashi Abe, PhD, that involved partially occluding blood flow to the affected limb for short workouts.<sup>2,3</sup> Owens did some reading, decided to give it a try, and found the results so promising that blood flow restriction (BFR) training soon became his specialty.<sup>4</sup> He still puts in time at Brooks, but he believes BFR may hold potential not only for those with war wounds, but also for high-level athletes and patients recovering from surgery. He’s now co-owner and director of clinical education at Owens Recovery Science, which is based in San Antonio but has clients nationwide.

*Figure 1. A patient does a leg lift while wearing a BFR cuff. (Photo by Jason Risner, courtesy of Owens Recovery Science.)*

## Possible mechanisms

Traditional guidelines suggest that to optimally gain size and strength in a limb, people need to perform resistance training using at least 70% of the concentric one-repetition maximum (1RM) force of which they’re capable.<sup>5</sup> However, as a 2016 literature review concluded, low-load resistance exercise combined with moderate BFR appears to facilitate hypertrophy and strength gains in athletes and others.<sup>6</sup> A key benefit is that the use of light loads can protect joints and other healing parts that might otherwise be damaged by the heavy loads typically used to build strength and mass.

In Japan the approach has been popular for years and is called Kaatsu,<sup>7</sup> but it’s still catching on in the US. Part of the problem is lingering uncertainty about exactly how it works. Researchers theorize that BFR may create a hypoxic environment that is then associated with increased metabolic stress, increased muscle fiber recruitment, cellular swelling, enhanced intramuscular signaling for protein synthesis, and proliferation of myogenic stem cells, all of which likely promote muscle development.<sup>6</sup>

It’s important to emphasize, too, that practitioners are talking about partial occlusion—not cutting off all arterial flow to the limb, as would be done in catastrophic injury or surgery—and for periods of just five to 10 minutes at a time.

Jeremy Loenneke, PhD, an assistant professor of exercise science at the University of Mississippi in Oxford, became interested in BFR a few years ago and has since become one of the world’s leading researchers in the field. Loenneke, a coauthor of a couple of the review studies just mentioned, told *LER* that the buildup of metabolites in the muscle being targeted using BFR may be important, as are increases in muscle activation.

“When you apply BFR, there’s some suggestion that you can increase type-2 [fast-twitch] muscle fiber recruitment, and typically you’re not going to recruit those fibers unless you’re exercising to failure,” Loenneke said. “When we restrict blood flow, we see high levels of EMG [electromyography] amplitude, which is comparable to what we see with lifting a heavy weight, and that may affect fiber recruitment. It’s also possible that you’re creating a hypoxic-like environment inside the muscles. But to be honest, we’re not exactly sure.”

Brian Clark, PhD, executive director of the Ohio Musculoskeletal and Neurological Institute, and a professor of physiology and neuroscience at Ohio University in Athens, became interested in BFR when he was conducting NASA-funded research into neural and muscular factors in muscle weakness.

“We know muscles adapt to strain, and that if you overload a muscle mechanically it stimulates cellular processes that result in growth, repair, and regeneration,” Clark said. “I suspect that a similar process happens when, instead of overloading it mechanically, you overload it metabolically.”<sup>8</sup>

According to Daniel Hollander, EdD, a professor of kinesiology who specializes in strength and conditioning at Southeastern Louisiana State University in Hammond, there’s still much to learn about such processes.

“I don’t think we understand half of what’s happening with BFR training, but one possibility is that you get an increase in anabolic hormones to the working muscle at a much lower intensity than you would with normal weight resistance,” Hollander said.





Figure 2. Johnny Owens adjusts a setting on a tourniquet worn by Marine Corps Staff Sgt. Brandon Kothman during BFR training at Brooke Army Medical Center, San Antonio, TX. (US Army photo by Robert D'Angelo.)

Hollander and colleagues reported in 2006 that BFR training elicited a greater growth hormone response than traditional training, in fact, but did not affect levels of resting total testosterone, free testosterone, or cortisol.<sup>9</sup>

"That's a positive adaptation, but the caveat is that you're not talking about one growth hormone, but rather hormones, some of which have different biologic availability than others," he said. "The benefit of those, though, is that you get muscle hypertrophy without the ligamentous stress of repetition at a higher intensity. There's an adaptation to the hypoxic environment similar to training at altitude, but in a more locally adaptive way."

## Potential risks

Some researchers, including Brian Clark, have investigated potential risks associated with BFR, such as nerve damage or deep vein thrombosis (DVT).

"I wrote an NIH [National Institutes of Health] grant to study BFR, but the criticism—and rightfully so—was that we had no clue whether it was safe," Clark said. "So I decided to look at those concerns."

In a 2009 paper coauthored with Todd Manini, PhD, Clark reported findings suggesting that BFR training doesn't affect blood clotting time or vascular function, and noted that vascular compression alone stimulates the fibrinolytic system without elevating the coagulation cascade.<sup>3</sup> The authors noted, however, that BFR may place demands on the cardiovascular system beyond those seen with traditional high-load exercise.

In another 2009 paper, Clark and his coauthors reported that, compared with low-load exercise without restriction, BFR training was associated with more severe delayed-onset muscle soreness; they also found that BFR with concentric exercise led to greater soreness than when it was used with eccentric exercise.<sup>10</sup>

A 2011 study from Clark and colleagues found that, over four weeks, both high-load resistance exercise and low-load BFR exercise increased strength without altering nerve or vascular function, and that both approaches increased fibrinolytic activity without altering markers of coagulation or inflammation.<sup>11</sup> In a 2016 paper, however, Clark and Manini reported a case (the second recorded) of exertional rhabdomyolysis—a serious kidney disorder—in a BFR user, and urged caution about the approach.<sup>12</sup> The first such case was reported in a 31-year-old Norwegian hockey player in 2010.<sup>13</sup>

Yoshiaki Sato, MD, PhD, one of the Japanese pioneers of the approach, has written that he himself had a serious side effect in the early days, as he was still refining the technique. Overzealous BFR training

gave him a blood clot in his leg, which traveled to his lung and nearly killed him.

"It is quite difficult to reduce blood flow by the appropriate amount in order to achieve beneficial effects," Sato concluded.<sup>14</sup>

Daniel Hollander reported in 2010 that BFR training was associated with alterations in pain and effort sense similar to those associated with higher loads but no occlusion.<sup>15</sup> There's a downside to inhibiting pain, he acknowledged; athletes could damage tissue without knowing it.

"If you attempt to partially occlude too soon during rehab, you could hurt yourself," Hollander said. "But, if you do it at a level you know won't be injurious, there could be a positive effect."

In a similar vein, patients could damage connective tissue because it doesn't gain strength in an environment of low mechanical loading; if muscles acquire disproportionate strength, patients could be putting their tendons at risk.<sup>6</sup>

Last year, Marty Spranger, PhD, an assistant professor of physiology at Michigan State University in East Lansing, published a paper in the *American Journal of Physiology - Heart and Circulatory Physiology* pointing out that reductions in blood flow to exercising muscle engage the exercise pressor reflex (EPR), which significantly contributes to the body's autonomic cardiovascular response to exercise.<sup>16</sup> Spranger and his coauthors noted that, in patients with cardiovascular diseases, the EPR can generate exaggerated increases in sympathetic nerve activity; as such, they suggested that it be used with caution in such patients, and could even pose risks to healthy individuals.

A team of University of Mississippi researchers, including Jeremy Loenneke, replied with a letter to the editor acknowledging the concerns and noting the


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Figure 3. Low-load resistance training with BFR can be conducted more often than traditional higher-load training—as often as twice daily for two weeks with a 20% 1RM. (Photo courtesy of Jeremy Loenneke, PhD.)

importance of customizing the amount of restriction to the patient.<sup>17</sup> Spranger and colleagues answered that determining such optimal values would be complex due to individual physiological differences related to EPR processing.<sup>18</sup>

“I fully agree with everything Spranger said,” Clark told *LER*. “The autonomic response to exercise certainly needs to be considered.” Loenneke agreed.

“Spranger brought up good concerns, things we need to think about before we prescribe BFR widely,” he added.

Most studies of BFR so far have included healthy participants and have not been designed to detect potential EPR effects, Clark noted.

“It’s all about the outcome variables you measure,” Clark continued. “We measured blood clotting factors, inflammatory factors, and vascular stiffness of the peripheral tissues. But it would not surprise me if the acute effects of BFR were different due to the exercise pressor reflex, in which a buildup of metabolites may feed back via sensory nerve fibers to the autonomic nervous system, which then increases sympathetic outflow that acutely raises blood pressure and total peripheral resistance. We didn’t see any issues in healthy young people, but you’ve got to be more careful when you move into other populations.”

That said, Clark noted that professional opinion about BFR varies widely.

“When I heard about BFR, my first concern was the risk of deep vein thrombosis, and when I talked to a general practitioner or a physical therapist, they had the same response,” he said. “But if I

talked to an orthopedic surgeon or a hematologist, they would not have the same level of concern. Even the case of rhabdomyolysis was rare, and you could argue that pretty much any exercise can cause it. Although I’m not convinced that the adaptations associated with BFR are any different than with other muscle-growth activities, I do think it has potential viability in patient populations where traditional exercise modalities are contraindicated because of joint-integrity issues or related problems.”

## Applications

Research suggests a few such possibilities, in fact. For example, BFR has been shown to be effective for early muscular training after anterior cruciate ligament reconstruction.<sup>2,19</sup> There’s also evidence to suggest that the modality may induce adaptation not just in muscle but in bone, possibly through altered fluid distribution.<sup>20</sup> Moreover, BFR appears useful for building strength in middle-aged people who are unable to perform resistance training with heavy loads.<sup>21</sup>

BFR also appears promising for female patients with osteoarthritis (OA); a 2015 paper from researchers at the University of Kansas and the University of Iowa found that it increased leg strength in women at risk for symptomatic knee OA compared with the same exercise program without BFR<sup>22</sup> (a parallel study in men showed no improvement over standard exercise<sup>23</sup>). In a Brazilian study published this May, 34 women with knee OA were randomized to do quadriceps strengthening either using traditional loading or lighter loads with BFR.<sup>24</sup> The two approaches led to similar improvements in pain, function, and quad strength, but those in the BFR group reported less anterior knee pain while training.

BFR could help older patients with problems other than OA, too.

“There are a lot of scenarios in the elderly where high-intensity resistance exercise can’t be done,” said Brian Clark.

“We’ve found that older people don’t like to lift heavy weights,” added Jeremy Loenneke. “This would allow them to get the benefits of lifting those weights without having to do it.”

The gains may not just pertain to weightlifting, for that matter. Researchers have shown that when elderly people trained five days a week for six weeks using low-workload walking with BFR, their knee extension, flexion torque, and thigh muscle cross-sections all improved to a greater extent than in a control group who walked without BFR.<sup>25</sup>

Of course, older patients are more prone than their younger counterparts to the potential cardiovascular risks associated with BFR training that have been acknowledged by Loenneke and others. Much of Loenneke’s work has focused on how to adapt this still-uncertain science for maximal benefit and minimal risk. In fact, all the clinicians *LER* spoke with emphasized the importance of patient-specific training protocols.

“How do we individualize this?” Loenneke asked. “What’s the lowest pressure we can apply and still see muscle adaptation? I think now that if you apply thirty percent of one RM at a moderate pressure, you’re probably maximizing the stimulus for muscle.”

In other words, if the maximum the person could lift in a given exercise was 100 pounds, the traditional target for training would be 70 pounds; with BFR, by contrast, it would be 30 pounds, though with more reps.

In a 2015 paper in *Sports Medicine*, Loenneke and his coauthors suggested guidelines for BFR training volume and frequency.<sup>7</sup> In terms of volume, they

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# MISSION POSSIBLE:

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Figure 4. National Football League players who have tried BFR training include the Houston Texans' Jadeveon Clowney, who was recovering from microfracture surgery on his right knee following a lateral meniscus tear.



noted that one popular approach consists of four sets of an exercise, with repetition goals of 30 in the first set, then 15 each in sets two through four, for a total of 75 reps. These are higher than the repetition volumes typically associated with high-load resistance training, but Loenneke pointed out that recent evidence suggests skeletal muscle hypertrophy may be more influenced by volume than by intensity.<sup>26</sup> In any case, doubling those numbers by repeating the protocol didn't increase the benefits, and the authors speculated that there may be a volume threshold beyond which muscles don't develop further.

Loenneke also noted that, early in training, participants may not be able to complete all of the reps dictated by such a protocol. In

such cases, clinicians should decrease the patient's intensity (eg, from 30% to 20% of 1RM) or increase inter-set rest periods beyond the usual 30 seconds; BFR thus modified still shows significant benefits. For that matter, patients new to BFR shouldn't regularly train to muscle failure until they become accustomed to it.

In terms of frequency, low-load resistance training with BFR can be conducted more often than traditional higher-load training—as often as twice daily for two weeks with a 20% 1RM, according to Loenneke's article. Such frequencies have reportedly not been associated with increased markers of muscle damage and oxidative stress.

For postsurgical patients, Loenneke and his colleagues have proposed progressive implementation of BFR from early rehab through a resumption of high-load resistance training. The protocol consists of BFR only during bed rest, followed by BFR plus low-workload walking, then BFR plus low-load resistance exercise, and finally BFR plus high-load resistance exercise.

Athletes seeking to prolong their careers could benefit from mixing some BFR training in with their usual regimens, the authors suggest, given that their joints, too, would be spared by decreased mechanical stress.

"Most people will use this to get better, then transition to normal exercise, but I don't see any reason to discourage them from using it long term," Loenneke said.

Some research supports the idea. For example, in one study from Japan, six-week strength gains were similar for individuals who did high-load resistance training with no BFR and those who did a combination of low-load resistance training with BFR and high-load training without BFR; both groups had greater increases than those who used BFR alone.<sup>27</sup> Another study found that, when college foot-

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ball players supplemented traditional strength training with low-load BFR training, they significantly improved their bench press and 1RM squat strength.<sup>28</sup> Other researchers, however, have reported insignificant additional effects by adding BFR to traditional training in fit individuals.<sup>29</sup>

## Customization

Some evidence suggests the response to BFR training may depend on the type of athlete, interestingly enough.<sup>7</sup> For example, researchers have observed that distance runners experienced significantly greater metabolic stress with BFR training than sprinters did;<sup>30</sup> this may occur because distance runners are more dependent on oxygen delivery than sprinters, who tend to be more accustomed to the anaerobic environment typical of BFR. More work remains to clarify such matters, but the findings highlight the advisability of customizing BFR training protocols to individual patients, as already noted.


Johnny Owens knows this from personal experience. After he'd received some attention for his work with injured veterans, he got a call from the Houston Texans, who asked him to try BFR techniques on several of their players, including linebacker Jadeveon Clowney, who was recovering from microfracture surgery on his right knee following a lateral meniscus tear. Reports from the team were positive; the Texans' director of sports medicine, Geoff Kaplan, told ESPN that the athletes who received BFR training were exhibiting better muscle control and progressing faster than team trainers were expecting.<sup>31</sup> Owens has since begun working for more than 20 college and professional teams in football, basketball, baseball, hockey, and soccer, and is involved in several ongoing clinical trials.

"We have to apply BFR training to different clinical problems," he said. "The amount of load, how you do it, how much you're doing, all might be different. Someone with a microfracture in their knee will have a very conservative protocol; he can't put any load through his knee at first. So we do exercises that are protective of his repairs and try to manipulate those with the tourniquet on to get an increase in the protein synthesis response. Then we move to a biking protocol; then we load in a protective range of motion based on the location of the lesion in the knee. It's a way to tackle the strength and hypertrophy phase of rehab, and to mitigate the effects of atrophy."

Owens eschews the tourniquets common to Kaatsu training, which aren't US Food and Drug Administration-approved as medical devices; instead, he utilizes a Delfi system similar to that used in surgery, which measures occlusion pressure with Doppler.

"Clinically, it's the safest we could find," Owens said. "Our target is 80% occlusion, but there are many variables in estimating that—limb size, tissue density, systolic blood pressure, cuff placement and width, the patient's gender—and the only way we can account for them all is with Doppler."

## Down the road

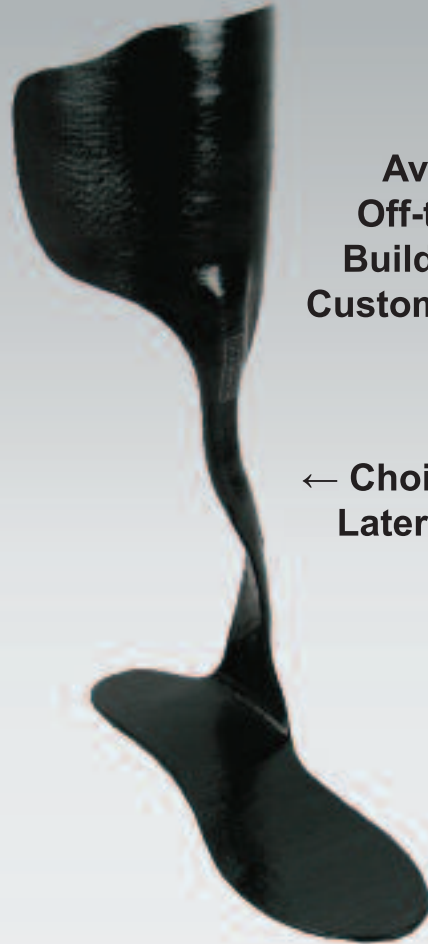
As clinical trial results continue to become available, and more clinicians explore the potential benefits of BFR training, it should become clearer how to use the technique in different patients for optimal strength and safety. For now, it looks like proponents have a natural motto at hand: less strain, more gain. 

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

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

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# ORTHOTIC DEVICES FOR THE WIN



## Understanding turf toe: The role of foot orthoses

By Patricia Pande, MCIScPT, CSCS, CPed

Turf toe is a common injury in football players competing on artificial turf, but it also occurs in soccer and baseball players on natural grass and other playing surfaces. Turf toe is a sprain of the capsule of the first metatarsophalangeal (MTP) joint; increasing grades of injury may include a strain or avulsion of the plantar plate. Depending on the directional torque on the plantar flexed foot, the medial collateral ligament (MCL) of the first MTP may also be avulsed.<sup>1</sup>

Typically, turf toe is characterized by a hyperextension of the first MTP joint and involves the capsuloligamentous structures and, often, the sesamoids as well.<sup>1-3</sup> Although turf toe also can be a hyperflexion injury, the two mechanisms warrant different modes of treatment. For clarity, turf toe in this article is defined as a hyperextension injury with pathology to the plantar aspect of the first MTP joint, including muscle, cartilage, and bone.<sup>4</sup>

Because of its varied prevalence, turf toe is likely more a function of the flexible cleats used in soccer and football than the playing surface, and might be more appropriately named “cleat toe.” Turf toe may be misdiagnosed if the pathology is limited to ligamentous damage, lacking the muscle, cartilage, or bone pathology associated with more severe grades of turf toe.<sup>4</sup>

Bowers and Morton<sup>5</sup> were the first to identify the turf toe injury. Shortly after the introduction of artificial turf in football, turf toe occurred at a rate of four to six injuries per season.<sup>6,7</sup> In 1990, Rodeo et al found turf toe in 45% of professional football players.<sup>8</sup>

More recently, researchers have noted turf toe incidence in collegiate football players as .62 per 1000 athletic exposures.<sup>9</sup> It's 14 times more likely to occur in games than in practice, and is most common in football running backs and quarterbacks.<sup>9</sup>

### Biomechanics

Turf toe occurs when the foot is held in plantar flexion while the first MTP joint hyperextends. This may involve contact from another player (eg, tackling) or a braking motion from the cleat catching in the turf while the player accelerates forward or changes direction.

The first MTP joint is a condyloid joint with two degrees of freedom. During the first 20° of dorsiflexion with the foot planted on the ground, the phalanx is stabilized and the first metatarsal rolls over its base. After 20°, the peroneus longus is activated and the first metatarsal slides in the direction of plantar flexion, with concomitant dorsiflexion at the first MTP joint.<sup>10</sup>

During gait, the first MTP joint undergoes a series of rolling,

sliding, and compression, with the final push-off effect enhanced by the plantar fascia and the muscular attachments.<sup>10</sup> During sports play, the first MTP joint is pivotal to running, accelerating, and jumping. During a running jump, it undergoes forces of up to eight times body weight; these forces can make the capsuloligamentous structures more vulnerable to a turf toe injury.<sup>11</sup>

Ongoing subclinical stress to the first MTP joint has been studied in basketball players; the first ray, however, is an important consideration for football and soccer players as well.<sup>12</sup> Its role in the windlass mechanism is most effective when the positions of the first metatarsal, sesamoid apparatus, and hallux are oriented with the plantar fascia or aponeurosis.<sup>13</sup> Without this orientation, the sesamoid apparatus is unable to exert a sling effect on the first metatarsal, and excessive dorsiflexion may occur.

Although turf toe is most common in running backs and quarterbacks, plantar loads (and risk of turf toe) are also very high in football linemen, as the first MTP joint is already subjected to increased tension.<sup>8</sup> If a lineman accelerates into contact with another player, the forces are further magnified at the first MTP joint.<sup>8</sup> This suggests that treatments to reduce stretching or excessive tension in the plantar capsule and ligament may help prevent turf toe injuries.<sup>4</sup> Such treatments could include the use of tape, stiff-soled footwear, and orthoses designed to reduce dorsiflexion of the first MTP joint.

Foot orthoses can be used to lower the head of the first MTP joint—for example, supporting the medial longitudinal arch elevates the base of the first MTP while lowering the head.<sup>14</sup> Performing a weightbearing Hubscher test before and after provision of an orthosis can help verify preservation of range of motion and function.<sup>14</sup>

### The role of the sesamoids

The medial and lateral sesamoids are embedded in the flexor hallucis brevis (FHB) and elevate the metatarsal head to reduce plantar trauma.<sup>15</sup> The medial sesamoid attaches to the abductor hallucis, the proximal phalanx, and the plantar fascia. The lateral sesamoid is connected to the lateral FHB and the adductor hallucis throughout the intermetatarsal ligament. Proper function of the sesamoids reduces the distraction forces on the plantar plate and may help to reduce the severity of a turf toe injury.<sup>4</sup>

First MTP joint flexion is accompanied by distal gliding and dorsal tilting of the sesamoids in the normal foot.<sup>16</sup> The integrity of the

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ligaments enhances the function of the sesamoid during cutting activities (involving high varus and valgus forces), which are often associated with turf toe.<sup>3</sup>

During sports, the hallux sesamoids are often traumatized, more commonly on the medial or tibial side, and with axial loading in a plantar flexed position.<sup>17</sup>

## Causes of turf toe in sports

There is a paucity of data identifying the primary cause of turf toe, however, much of the literature cites plantar flexion with toe extension. As such, attempts have been made to prescreen athletes for tight Achilles tendons and restricted toe extension.<sup>18</sup>

Prior injury that results in hallux limitus is positively associated with turf toe injury involving the contralateral limb, while decreased range of motion at the first MTP joint has been disputed as a predictive factor.<sup>19</sup> Hallux valgus is often associated with turf toe, and may be a complicating factor in conservative or surgical treatment.<sup>4</sup> A survey-based study by Coker et al<sup>7</sup> suggested an association between turf toe and pes planus, but those results have not been reproduced, and longitudinal prospective studies have not been conducted to examine the association.

Artificial turf produces a higher peak torque at the shoe-surface interface than natural grass. Whether this leads to increased injury is still a source of contentious debate.<sup>20,21</sup> The obvious performance benefits associated with newer generations of artificial turf—including increased speed, acceleration, and torque at the shoe-surface interface—often preclude safety considerations, especially in light of the mixed research results.<sup>20,22</sup>

Studies comparing rates of injuries sustained on grass and synthetic turf are confusing, and it is difficult to extrapolate from studies of anterior cruciate ligament (ACL) and ankle injuries, for example, to injuries involving the first MTP joint. There are no randomized prospective longitudinal studies of different foot types or footwear choices that assist in our understanding of the mechanism of injury. Most recently, changes in style of play have been suggested as a cause of injury,<sup>23</sup> and this remains an intriguing new area of research.

Soccer cleats have evolved over time to enhance performance and reduce midfoot and ankle injury. Unfortunately, the switch to more restrictive midfoot stabilization engenders overcompensation, often in the form of increased forefoot flexibility.<sup>24</sup> Football shoes have also become lighter and more flexible, qualities that may enhance players' performance and improve their feel of the ground.

Studies on the role of cleats in injury have focused on the ACL

and ankle sprains. Research has shown the location and number of cleats are factors in reducing varus and valgus translation at the foot, which can help reduce stress on the collateral ligaments and capsuloligamentous structures.<sup>25</sup>

## The role of orthoses

Clinically, foot orthoses are typically used to treat first MTP sprains; however, ultra-rigid carbon fiber is not well tolerated by athletes as it impedes form and function at push off. A prophylactic homopolymer polypropylene foot orthosis with a first ray indentation also was not embraced by most of a small sample of 24 football players;<sup>26</sup> only one player wore the orthoses every day and just six wore them "sometimes or infrequently." The most commonly cited reasons for noncompliance included discomfort and pain from the weight and fit, as well as the perception of performance-inhibiting characteristics associated with the devices.<sup>26</sup>

Turf toe injuries may be career-changing for many athletes. The return to sports is often slow (up to 16 weeks), depending on the severity of the injury and the position played.<sup>19</sup> The ultra-rigid carbon fiber orthosis that is often prescribed for more severe injuries may impede the rocker action of the foot and, as mentioned, is not popular with athletes.<sup>18</sup>

Treatment must mitigate the deleterious forces on the foot with the following orthotic strategies:

1. Reduce impact loading without the use of rigid materials that will restrict sesamoid function and increase the risk of noncompliance by the athlete.<sup>26</sup> Using more flexible carbon fiber that allows more natural movement will be better accepted.<sup>18</sup>
2. Allow the first metatarsal to function properly without blocking or accelerating plantar flexion and sliding of the metatarsal head.<sup>20</sup>
3. Accommodate or dissipate forces associated with pivoting, jumping, landing, push off, and rapid changes in direction, but without inhibiting performance.<sup>20,26</sup>
4. Allow for activity of the peroneus longus, as this is an essential stabilizer (plantar flexor) of the first ray during push off in sports.<sup>27</sup>

Turf toe in cleated sports will continue to cause concern. Our level of knowledge and biomechanics must meet this challenge. This topic is fraught with discrepancies on classification and treatment, with a lack of compliance that is not paralleled in any sport. (ler)

*Patricia Pande, MCIScPT, CSCS, CPed, is a physical therapist, pedorthist, and strength and conditioning specialist based in Durham, NC. She is the founder of FootCentric, an online continuing education company dedicated to comprehensive, multidisciplinary foot treatment.*

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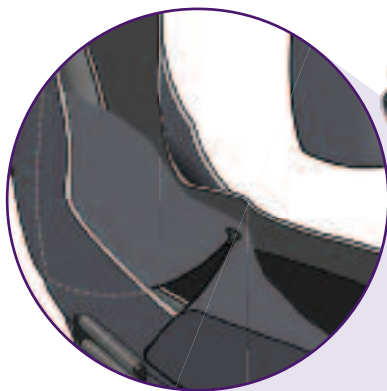
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## New healing factors take ulcer care to the next level

Support is growing, in the medical literature and in clinical practice, for the use of skin substitutes and other advanced biologic therapies in chronic diabetic foot ulcers. But researchers and practitioners remain uncertain as to which of these advanced products are best for which patients.

By Hank Black

Call them cellular and tissue-based products, bioengineered tissues, or skin substitutes. Regardless of the nomenclature, the use of advanced biologic therapies for treatment of diabetic foot ulcers (DFUs) has grown dramatically in recent years. And the options are welcomed as clinicians seek to cope with the large percentage of these wounds that fail to heal even with the most rigorous application of conventional techniques.

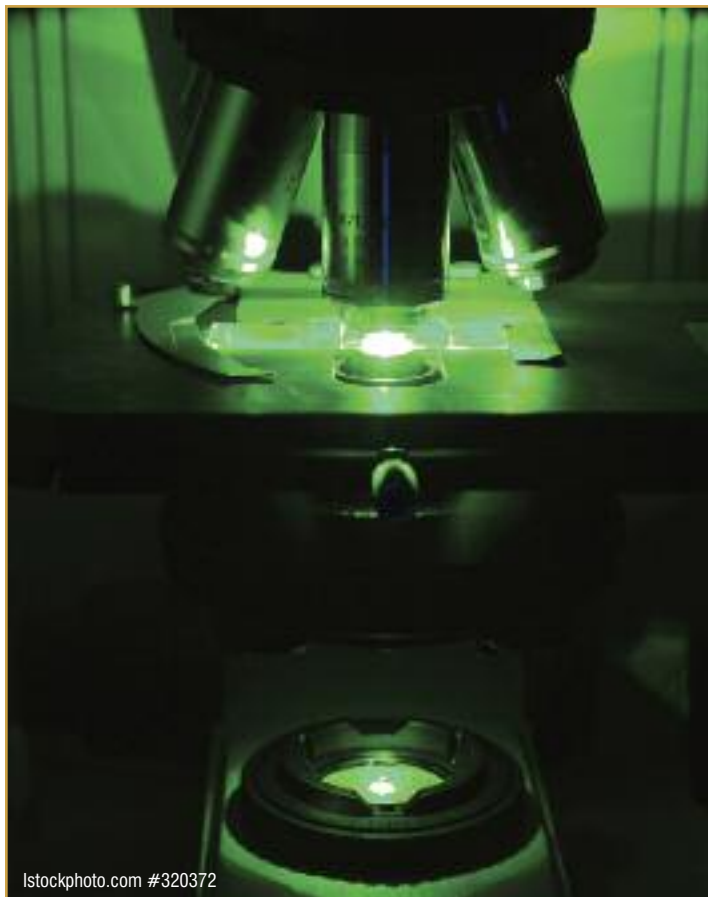
Skin substitutes can consist of bioengineered or artificial skin, autografts, allografts, xenografts, or a combination of these. They may provide an acellular scaffolding for the body to populate with its own biology, perhaps augmented by one or many growth factors and nutrients that can induce healing. They may supply living human cells that come with their own healing factors. And many experts see great promise for these and other products, such as mesenchymal stem cells that bring even more—and different—factors to the mix, including some necessary mechanisms for wound healing.

“It’s an interesting time for biologic products for chronic diabetic foot ulcers, because historically they were used to replace deficiencies in the wound, such as collagen, and now the approach is to use stem cells to give the wound factors it’s never had to begin with,” according to Adam S. Landsman, DPM, PhD, chief of podiatry at Cambridge Health Alliance and an assistant professor of surgery at Harvard Medical School in Boston.

The need to heal chronic ulcers is evident. Almost 30 million people in the US have diabetes.<sup>1</sup> As many as one-fourth of patients with diabetes will develop a foot ulcer (DFU) during their lifetime.<sup>2</sup> A DFU presents significant physical, social, and financial burdens, including a high risk of lower extremity amputation.<sup>2,3</sup> Nonhealing ulcers are the leading cause of eventual amputation.<sup>4</sup> And at least one third of the \$176 billion in direct costs for treating diabetes and its complications is associated with DFU therapy.<sup>1,3</sup>

The standard of conventional wound care consists of sharp debridement, moist dressings, stringent offloading, and infection control.<sup>5,6</sup> With conventional wound care, healing rates are typically

Although clinicians need better means of diagnosing all that a wound requires to heal, they are getting better at determining what is keeping a wound from healing.



low—a 1999 meta-analysis reported only 24% of ulcers healed at 12 weeks and only 31% at 20 weeks<sup>7</sup>—so it's no wonder that excitement abounds over the technological advances developed during the past few years.

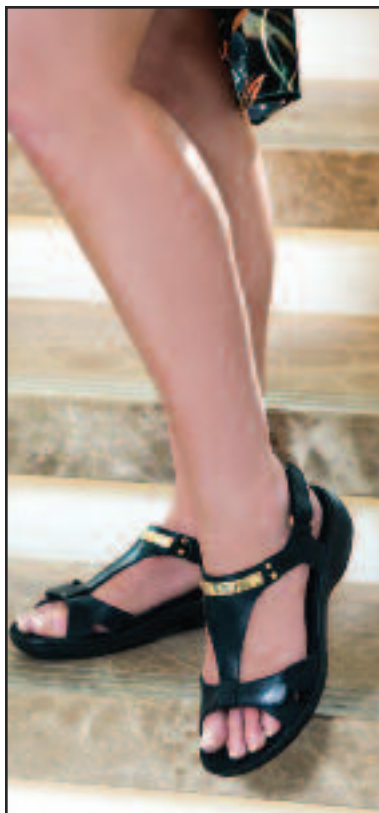
Six years ago, a consensus panel of multidisciplinary experts reviewed the evidence for various options available for DFU care. The panel concluded advanced wound care, including biologics, should be considered the new standard of care for slow-healing wounds rather than a last resort.<sup>8</sup>

"There has been a rapid expansion of interest in new advanced products in recent years, although there's not an overall consensus on which are better than others," according to Rajiv Nathoo, MD, a clinical dermatology resident at the University of Florida in Gainesville, who coauthored an overview of the advanced wound care field in 2014.

The review concluded that, though modern alternatives do increase healing rates by providing relevant matrix, growth factor, and paracrine signaling abilities, an ideal substitute does not yet exist.<sup>9</sup> A recent Cochrane review<sup>10</sup> that included 17 studies of skin grafts and tissue replacements in people with diabetes showed a higher healing rate and slightly fewer amputations compared with standard care alone, but the data were not sufficiently robust to conclude that one therapy was more effective than another. The review noted strong industry involvement in all but two studies. In addition, only four of the trials performed a head-to-head comparison of products.

## New perspectives

Paul J. Kim, DPM, MS, director of research in the Department of Plastic Surgery at Georgetown University in Washington, DC, said



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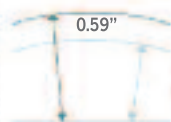
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that, until recently, his institution preferred to use proven cellular products. But results of a randomized controlled trial<sup>11</sup> of a new placental product influenced a change. The new product provides a cellular matrix designed to preserve the native components of the human placental membrane in a cryopreserved product.

"This product showed value with its greater than sixty percent healing rate, but even more significant was that the majority of participants in the control group who did not heal and were crossed over to the treatment arm did go on to heal," Kim said.

He also found value in the recent trial of an acellular bilayer product that uses shark chondroitin-6-sulfate, bovine type 2 collagen, and a silicone layer. It acts as a scaffold for vascular ingrowth and host fibroblast population.<sup>12</sup>

As an indication of the interest in the promise of placental products, Kim said, five such studies are underway at Georgetown.

Best practice guidelines for wound care published in recent years acknowledge a role for skin substitutes in nonhealing foot ulcers, but do not delineate specifics.<sup>13,14</sup> Some experts believe one key to success is the use of multiple growth and other factors.

"More is better," said John S. Steinberg, DPM, professor of plastic surgery at Georgetown University and codirector of the Center for Wound Healing at MedStar Georgetown University Hospital. "We've moved away from the original, cellular-based matrix products because placental-based therapy seems to have some merit linked to its stem cell activity that provides a more robust biologic environment to the wound."

Steinberg and Kim were coauthors of a recent publication<sup>15</sup> that divided bioengineered alternative tissues into dermoconductive and dermoinductive categories. The former refers to products that include cells such as fibroblasts and keratinocytes, which provide essential growth factors into the wound to activate new tissue. The dermoconductive category includes products that provide a scaffold in the wound for ingrowth of the surrounding host tissue. A third category includes dermogenic products that utilize stem cells.

Kim noted that even the most rigorously performed studies have top healing rates between 60% and 70%.

"The smaller studies are for the most part not well designed or analyzed and had a significant amount of industry bias," he said. "One trial reported a 90% success rate for healing, which is an obvious outlier."

## Too good to be true?

Indeed, much of the chatter in the field is about the 90% to 95% healing rate reported by Zelen et al for a dehydrated human amnion/chorion membrane allograft.<sup>16</sup> Most specialists interviewed for this article noted the limitations of that trial (the authors did not respond to requests for comment). Landsman, for example, said some wounds in that study were as small as 1 cm in diameter and may well have closed regardless of the biologic used.

"It's not clear that the biologic was what made the difference in healing," he said. "When you look at larger wounds and follow them for a long time, the data start to make more sense: You don't see the ninety-percent healing rate any longer. There's no way that an adequately powered study would ever have a ninety-percent closure rate; it's too good to be true."

Yet some clinicians are using that particular amnion/chorion technology in selected cases. Brandon J. Hawkins, DPM, CWS, medical director of the Stockdale Podiatry Group in Bakersfield, CA,

*Continued on page 34*

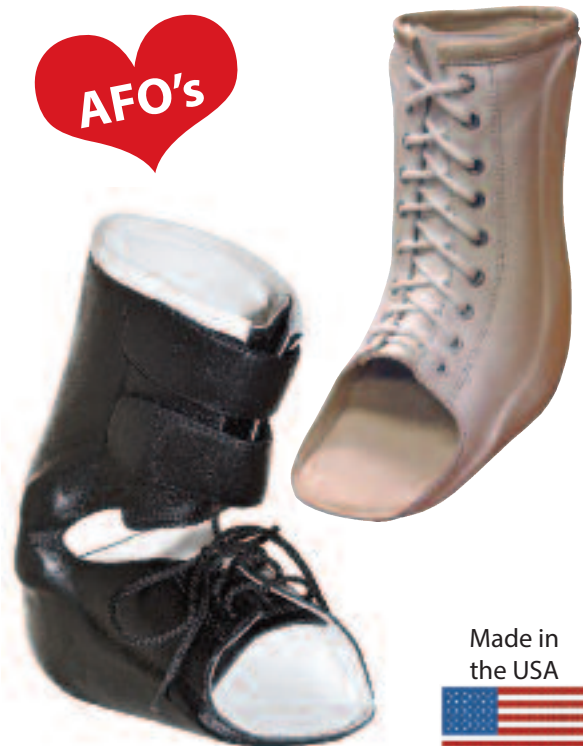
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includes it among other biologics for hard-to-heal chronic DFUs.

"There are different placental grafts out there and this is the only one with both amniotic and chorionic properties," Hawkins said. "I was skeptical of the data at first, but its high rate of wound healing seemed consistent. We have had very satisfactory results, although real-life experience and wounds do not match that of clinical trials. I don't have the luxury of screening for uniform off-loading compliance."

Hawkins said he especially likes the micronized version of the product for use in tunnel wounds and those with irregular borders. He recently published a small series of such cases.<sup>17</sup>

"I think advanced biologic products are now being used mainly in specialized wound centers because of insurance issues, but costs should come down with greater availability of the new technologies," he said. "I still use a lot of other types of grafts. If you put a certain graft on and it doesn't work for that patient, you try another. There's not one catch-all product for every wound."

Landsman said the particular needs of the wound should dictate which biological treatment should be used.

"You can go with the product that only offers fibroblasts, the one that offers fibroblasts and keratinocytes, or something that offers both plus a full array of collagens that are found in the skin," he said. "All things being equal, if you're going to offer biologics at all you might as well go for the one that's most complete, because there's typically not much of a price difference. More is better, in that case."

A potential advantage of placental products, Landsman said, is



that they offer additional factors.

"You're getting collagen that primarily is not the type found in the skin, for example. Traditional biologics offer large quantities of fibroblasts and keratinocytes, cell lines that primarily produce collagen and platelet-derived growth factor that stimulate blood vessel growth, cell division, and attract cells from the host into the wound," he said. "An amniotic product, on the other hand, produces a different set of growth factors, ones that are not present in the wound bed. That includes one in particular called tIMP [tissue inhibitor of metalloproteinase], a potent anti-inflammatory and stimulator of blood vessel growth."

Although clinicians need better means of diagnosing the full range of what a wound requires, they are getting better at determining what is keeping a wound from healing, Landsman said.

"If you see it needs collagen, I would recommend a biologic with a long-standing track record. But, if it needs blood vessel development and anti-inflammatory action, I might use an amniotic-derived product first, then transition to the traditional product," he said. "I take my best guess as to what will heal a chronic ulcer, but if it's not working after four weeks I check to see if there's too much biofilm, if the patient is noncompliant, or something else. If those aren't a problem, I change therapies monthly, cycling through my options."

### Diagnostics: The next wave

Researchers are looking for more robust diagnostic tests for chronic wounds, he said.

"That's the next wave of wound care," Landsman said. "Detection systems for MMP, a marker of inflammation, are clearly in development now. We are looking for a wound care 'dipstick,' a sensor to measure everything from pH to the bacterial level. For example, we are using microvascular analysis with infrared spectrophotometry to determine microcirculation in the wound surface. These are the types of tools that well-equipped, exceptional wound centers will have within the next few years."

Yet, most agree that, even with the increased rates of healing with the alternative products, complete success and the ability to heal practically every wound awaits better models of who will benefit from which product, and how best to analyze wound conditions and build more predictive models from the many factors inherent in each chronic wound.

Steinberg said the most frequent users of biological alternatives when a wound stalls are in tertiary wound centers, but that the products are increasingly being used in smaller centers.

"Impediments to use might include cost, although reimbursement is generally available, and adequate monitoring and handling, especially as to temperature control for cryopreserved products," he said. "And then there is the fact that the treatments address only the biology of the wound and not necessarily the underlying cause, which may be infection, ischemia, or biomechanics. There's also concern about biofilm, which may reform within hours of debridement and promote inflammation. Perfusion may be stalled by micro- or macrovascular disease. And bony prominences, tendon contraction, or abnormal gait patterns can result in ulcer recurrence."

Even with use of an advanced product with a multitude of stimulatory and healing factors, it's rare to achieve more than a 65% to 70% complete healing rate after 12 to 20 weeks.

"There are host factors involved that no one understands well,"

*Continued on page 37*

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Kim said. “We haven’t identified the confounding autoimmune processes that are inhibiting wound healing, which may include nutritional factors and other inherent immune-compromising factors that will keep us from ever getting to one-hundred percent complete healing.”

Patient compliance may also be an issue, which is why most experts interviewed for this article say they advocate total contact casting or other nonremovable off-loading devices.

“Pressure offloading is crucial to healing of diabetic foot ulcers,” Nathoo said. “You can have the best graft, durable, with adnexal structures and stem cells, but if the patient is applying pressure—knowingly or not—the success of healing will be diminished.”

There are concentrated efforts to determine the factors involved in healing and develop models to predict which wounds can be successfully treated. A recent paper<sup>18</sup> sought to pinpoint early which wounds would not heal with standard care and should be treated with advanced products such as skin substitutes.

“We know that the duration of the wound trajectory is a negative prognostic factor, so the earlier the treatment, the better off you are,” said coauthor Robert S. Kirsner, MD, PhD, professor and chair of the Department of Dermatology and Cutaneous Surgery at the University of Miami in Florida. “Almost everybody adheres in principle to the Peter Sheehan model of going to advanced products if the wound hasn’t achieved at least a fifty percent reduction in area in four weeks,<sup>19</sup> but, in theory, if you knew at two weeks the wound wasn’t going to heal, that would be the even better time to apply advanced therapy. In our study we had a thousand different parameters from more than thirty-five thousand patients to develop a better predictive model. These data suggest that you could predict sixteen-week healing with eighty-five to ninety-percent accuracy.”

## Cost considerations

The high cost of biologic care is, of course, an inhibiting factor for many clinicians and patients. Standard care for a nonhealing ulcer carries an average cost per ulcer episode of \$13,179, with higher grade ulcers costing as much as \$27,600 per episode.<sup>20</sup> Wu et al determined the costs associated with treating a DFU using advanced technologies can be as high as \$45,000.<sup>21</sup>

Still, many believe the additional benefits of biologic therapies will justify the higher pricetag. But so far that remains to be demonstrated.

“There’ve been cost-utility analyses,” Kim said, “but nobody’s ever done cost-effectiveness studies, which require calculations of quality-adjusted life years utilizing quality of life surveys such as SF-36.” The SF-36 is the 36-item Short Form Health Survey used by Medicare and managed care organizations to monitor and assess care outcomes.<sup>22</sup>

The ability to make early predictions about which patients will benefit from biologics, without having to spend four weeks on standard care as is typically required for reimbursement now, could make an even stronger cost-benefit argument.

“Despite the higher up-front cost of these advanced products, we might be saving the economy money because of the higher cure rates and quicker resolution of chronic diabetic foot ulcers,” Nathoo said. “Payers need more long-term vision to recognize this fact.” (ler)

Hank Black is a freelance writer in Birmingham, AL.

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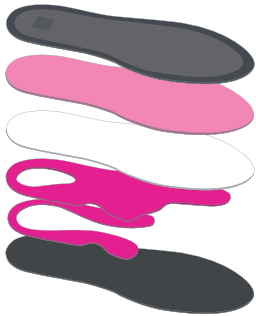
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## Lower extremity strength and injury risk in runners

Study findings regarding strengthening interventions in runners with patellofemoral pain syndrome have been inconsistent, perhaps because specific subgroups are more responsive than others. Preliminary research suggests high school runners may make up one such subgroup.

By Lace Luedke, PT, DPT, PhD, OCS, CSCS

Running continues to be a popular recreational activity, with more than 28 million Americans running 50 or more times per year in 2014.<sup>1</sup> However, while running confers many health benefits, the injury incidence is high, with reports of 19.4% to 79.3% of runners experiencing injury.<sup>2</sup> The knee, lower leg, and foot are the most commonly injured locations in runners,<sup>3</sup> and strengthening exercises are frequently used for the treatment of injured runners to address areas of impaired or asymmetrical strength.<sup>4-7</sup> Strength training has been associated with improvements in running economy,<sup>8</sup> and strengthening exercises are often suggested for prevention of common running injuries.<sup>9-13</sup> Although it's plausible that strengthening interventions may reduce injury risk in runners, the current evidence to support these interventions is lacking.

### Strength impairments in injured runners

Most evidence available on the relationship between lower extremity strength and injuries in runners comes from cross-sectional studies on recreational runners. Strength impairments in injured runners are common. In a cross-sectional study of 25 recreational runners, Ferber et al observed that runners with patellofemoral pain syndrome (PFPS) presented with a 30% deficit in hip abductor strength compared with asymptomatic runners.<sup>12</sup> In another study, runners with PFPS demonstrated weaker hip abductor muscles than healthy runners, both prior to and after an exhaustive treadmill run.<sup>14</sup>

Hip abduction strength deficits have also been reported in the involved limb of female runners with iliotibial band syndrome.<sup>15</sup> Similarly, in a cross-sectional study of 60 recreational runners, Niemuth et al found that runners with overuse injuries displayed worse hip abductor strength in their involved limb compared with noninjured runners.<sup>16</sup> In athletes with PFPS, less hip abduction and external rotation strength has been reported in the involved limb than the uninvolved limb; the same study reported global hip strength impairments in those with PFPS, compared with age- and sport-

In a recent study, high school runners with weaker hip abductor and knee strength values had a higher risk of anterior knee pain than their stronger counterparts.



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matched women without PFPS.<sup>17</sup> However, a more recent study on female runners in early stages of PFPS did not find significant hip abduction strength asymmetry, and hip abduction strength in hip extension was not impaired relative to noninjured runners.<sup>18</sup>

In a cross-sectional study of 169 recreational runners, Duffey et al reported that decreased peak knee extensor torque was a predictor of anterior knee pain (AKP).<sup>19</sup> Knee extensor strength was also decreased in recreational runners with chronic low back pain.<sup>20</sup> In contrast, Messier et al reported similar knee extensor and flexor strength values among recreational runners aged 16 to 50 years with and without PFPS, but the runners with PFPS tended to have greater knee flexion and less knee extension endurance bilaterally than controls, despite unilateral symptoms.<sup>21</sup>

Strength impairments have also been reported in runners with calf and foot injuries. In a sample of 12 female marathoners, decreased toe flexor strength was associated with a higher rate of posterior-medial shin pain and a lower arch.<sup>22</sup> Lower peak plantar flexion torque than healthy runners was observed at 180°/sec in runners with Achilles tendinitis<sup>23</sup> and at 60°/sec and 180°/sec in runners with plantar fasciitis.<sup>24</sup>

## Strength and running injury risk

While strength impairments are often observed in injured runners, whether these impairments are causative factors or secondary to the injury is not clear.<sup>11</sup> Prospective studies assessing strength values prior to injury occurrence may help determine which strength impairments are risk factors.

Hip muscle strength and function may be risk factors for knee injuries.<sup>25</sup> A lower preinjury hip external-to-internal rotation strength ratio was associated with increased AKP risk in a prospective study of 98 high school distance runners.<sup>26</sup> In a study of more than 600 novice adult recreational runners, those with higher eccentric hip abductor strength had a lower risk of developing PFPS.<sup>27</sup> In contrast, a study of 77 novice female distance runners reported that hip flexor, extensor, abductor, adductor, external rotation, and internal rotation isometric strength did not predict which runners would experience PFPS during a 10-week running program.<sup>28</sup> Knee flexion and extension strength may influence knee injury as decreased isometric hamstrings and quadriceps strength were significant risk factors for AKP in US Naval Academy midshipmen.<sup>29</sup>

With regard to shin injuries, Verrelst et al found that decreased hip abduction strength predicted the development of exertional medial tibial pain during running in a prospective study of 95 female physical education students.<sup>30</sup> In contrast, greater hip abduction strength was not protective against medial tibial stress syndrome or tibial stress fracture in a study of 230 high school runners.<sup>31</sup> In a prospective study



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of 125 collegiate cross country runners, distal strength values didn't influence shin injury incidence, as reduced isotonic ankle plantar flexor endurance was not significantly associated with incidence of exercise-related lower leg pain.<sup>32</sup> Additionally, in a study of 146 collegiate athletes, isometric strength of the ankle plantar flexors, dorsiflexors, invertors, and evertors was not associated with occurrence of medial tibial stress syndrome.<sup>33</sup> In a study that assessed isometric trunk, hip, and knee strength in recreational runners, decreased knee flexor strength was associated with the development of Achilles tendon pain in runners.<sup>34</sup>



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Continued on page 42

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Although strength was not assessed in Bennell et al's prospective investigation of 111 track and field athletes aged 17 to 26 years, female athletes with stress fractures (most frequently to the tibia) had less lean mass in the lower limb and smaller calf girth than female track and field athletes who did not incur a stress fracture.<sup>35,36</sup> Track and field athletes with a 1-cm deficit in corrected calf girth were also four times more likely to incur a stress fracture.<sup>35</sup> Bennell et al also found that corrected calf girth and lower limb lean mass were positively correlated with tibial and fibular bone density,<sup>37</sup> suggesting lean mass may be protective against stress fractures in runners.

## Our recent study

Like recreational running, high school cross-country participation is also very popular, with more than 30% of high school athletes participating in cross-country in the past decade.<sup>38,39</sup> However, 59% to 68% of high school distance runners report a history of running injury.<sup>40</sup> In high school runners, the shin and knee have been the most frequently reported injured areas, together representing 48% of new injuries and 59% of reinjuries.<sup>40,41</sup> We conducted a study to determine if hip and knee strength was associated with the incidence of shin and knee injuries in high school cross-country runners.

At the start of the interscholastic season, 68 high school cross-country runners (47 girls) were tested for peak isometric hip abductor, knee extensor, and knee flexor strength using a handheld dynamometer. Values were normalized to body mass. During the season, runners were tracked for athletic exposures (practice and competition participation) and occurrences of AKP and shin injuries that resulted in time lost from practice or competition. Runners were categorized by their strength values into weakest, middle, and strongest tertiles for each muscle group; the strongest group was used as the reference group.

Runners in the weakest tertiles for hip abductor, knee extensor, and knee flexor strength were more likely to experience AKP than those in the strongest tertile.<sup>42</sup> The incidence of shin injury was higher for runners in the weakest tertile for hip abductor strength than the strongest tertile, but the relationship was not statistically significant. Runners in the weakest tertiles for knee extensor strength and knee flexor strength did not have an increased risk of shin injury.<sup>42</sup>

In our study, high school runners with weaker hip abductor and knee strength values had a higher risk of AKP than their stronger counterparts. However, we concluded further evidence is needed to determine whether screening for strength impairments and interventions targeting strength impairments will reduce risk of running injuries.

## Clinical implications

The inconsistent findings in the literature on associations between lower extremity strength and running injury occurrence are likely because running injuries are multifactorial. Anatomy, biomechanics, and training load may all contribute to injury occurrence.

Strengthening may improve runners' ability to tolerate loads associated with running. Theoretically, screening for hip muscle weakness and adding strengthening exercises may help prevent AKP in female athletes.<sup>17</sup> Additionally, strength training of the hamstrings in runners has been proposed to lower the risk of knee and soft tissue injuries,<sup>13</sup> as the hamstrings are thought to be important for maintaining stride mechanics due to their role in controlling braking forces at the knee.<sup>43</sup>

While muscle strength may improve tolerance of loads during running, another reason for inconsistencies in the reported relationships between strength and injury risk may be that strength is typically assessed isometrically. It's unclear how much of an influence peak isometric strength has on the dynamic task of running, and specifically on prolonged running in the presence of muscular fatigue.<sup>44</sup> Schmitz et al found that, while isometric hip strength values were similar between novice and experienced runners, hip internal rotation motion during running was higher in the novice runners,<sup>45</sup> suggesting isometric strength may not correlate strongly with muscular control and kinematics during running.<sup>44-46</sup>

Strengthening exercises are effective for increasing strength. Runners who, in addition to their running, participated in a six-week strengthening program for hip abductors and external rotators increased their strength and reduced hip internal rotation during running.<sup>46</sup> Although this intervention appeared to influence injury risk factors, injury incidence after the intervention was not assessed directly.<sup>47</sup>

In other studies, hip strengthening exercises in runners with PFPS increased their hip strength values without changing running mechanics,<sup>48</sup> while heavy strength training in female runners resulted in improved 1RM (one-repetition maximum) for leg exercises.<sup>49</sup> Active individuals with PFPS who participated in six weeks of either hip or knee strengthening had similar success rates for improvements in symptoms and function and increases in strength parameters.<sup>50</sup> However, participants in the hip-strengthening group started experiencing significant improvements in self-reported pain at three weeks, while those in the knee-strengthening group started at four weeks.<sup>50</sup>

With respect to strengthening exercises for running injury prevention, a preconditioning program implemented with the intent of

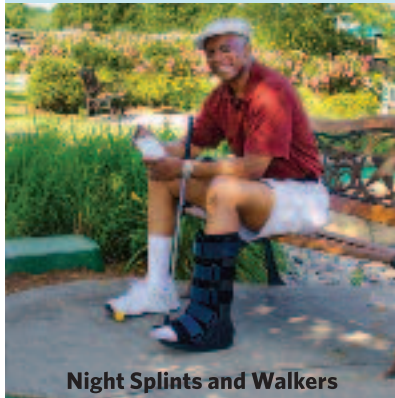
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improving strength and load tolerance in 432 novice runners didn't significantly reduce incidence of running-related injury.<sup>51</sup> The experimental preconditioning program included four weeks of progressive walking and hopping before starting a nine-week running program; injury rates during the nine weeks of running were similar for the preconditioning program participants and nonparticipants.<sup>51</sup>

In other sports, strengthening programs added to training have reduced injury rates. A structured warm-up program to improve neuromuscular control, balance, and strength in youth handball players reduced the injury rate in the intervention group (.5 injuries per 1000 player hours) compared with a control group (.9 injuries per 1000 player hours).<sup>52</sup> In adolescent soccer players, an intervention group added two to three sessions of plyometrics per week and strengthening to their regular training program for 12 weeks. Over the course of the season, those in the experimental group experienced a lower rate of injuries lasting three or more days than the control group (.70 injuries per 1000 hours of sport exposure vs 2.32 injuries per 1000 hours).<sup>53</sup>

In elite soccer players, adding eccentric and concentric hamstring strengthening exercises improved hamstring strength and reduced hamstring injury incidence.<sup>54</sup> Another study on elite soccer players noted fewer muscular injuries with the addition of functional strength, proprioceptive, core stability, and agility exercises.<sup>55</sup> A group of female floorball players participating in a neuromuscular training intervention including balance, hopping, and strengthening exercises had an injury

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rate that was 33% of the rate for the control group.<sup>56</sup>

Although each of these programs was associated with decreased noncontact injury rates in their respective sports, the programs included numerous exercises that may have improved attributes other than strength, including neuromuscular control.

## Conclusion

The use of targeted strength interventions in runners may reduce injury risk for some types of running injuries, but at this time, the evidence is limited. Considering the scarce evidence on strengthening for injury prevention in runners, any potential interventions may be most beneficial if focused on populations known to have a high risk of running-related injury, such as novice runners<sup>57,58</sup> and female high school runners.<sup>40,59</sup> Based on available prospective evidence, the addition of hip abduction strengthening exercises to training programs for runners is a low-risk intervention that may reduce the risk of PFPS, one of the most common injuries in runners.<sup>27,50</sup> Further research is needed, however, to determine conclusively whether screening for lower extremity strength and implementing strengthening interventions is beneficial for reducing injury risk in runners. 

*Lace Luedke, PT, DPT, PhD, OCS, CSCS, is a lecturer in the Department of Kinesiology at the University of Wisconsin-Oshkosh.*

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## Limb length discrepancy: When, how to intervene?

Limb length discrepancies (LLDs) as small as 1.5 cm can significantly affect gait, and some clinicians choose to intervene in cases of even smaller discrepancies. Many LLDs can be addressed orthotically, but surgical techniques are becoming less invasive and more effective.

By Cary Groner

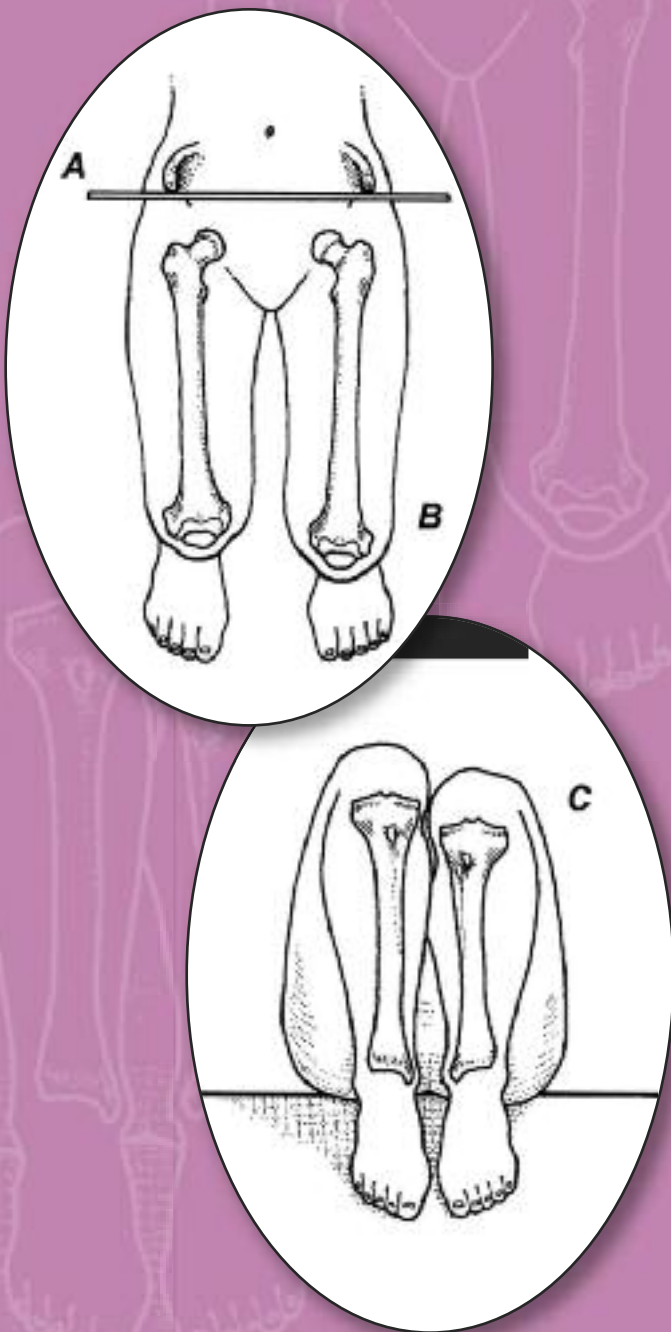
An old Scottish myth has it that the wild haggis—a small fictional creature typically rendered as something like a cross between an electrified hedgehog and Phyllis Diller—comes equipped with legs that are longer on one side than the other. The asymmetry helps it circumambulate the steep mountainsides of its native terrain, if only in one direction, goes the tale.

It's an amusing concept, but unfortunately there's a nonmythical human corollary: Leg-length discrepancies (LLDs) afflict a variety of people, including children with cerebral palsy, people who've had hip replacements, and those with scoliosis, pelvic obliquity, or certain muscle contractures.

According to some studies, LLDs are quite common—they've been reported in more than 90% of schoolchildren,<sup>1</sup> and nearly half of athletes may have some degree of discrepancy<sup>2</sup>—but most of these cases don't lead to symptoms. More severe LLDs, by contrast, may be associated with complications that include weakness, nerve injury, joint stiffness or dislocation, chronic pain, and arthritis.<sup>3</sup>

Research has quantified some of the effects of LLDs. In one study, for example, the authors reported that, when LLDs were artificially imposed on 44 older adults by applying platforms of varying thicknesses to one of their feet, they experienced significant quadriceps fatigue in the longer limb, and the applied LLDs caused walking difficulty beginning at 2 cm.<sup>4</sup> Similarly, a recent article in *Gait & Posture* reported that, when 19 healthy individuals wore sandals of varying thicknesses to give them a discrepancy of 1.45 cm, the LLD affected pelvic motion in the frontal plane despite the participants' compensation strategies.<sup>5</sup> Other studies have shown that LLDs are associated with standing fatigue<sup>6</sup> and the risk of plantar fasciitis in the longer limb.<sup>7</sup>

Although a discrepancy that may not cause symptoms for one person may lead to severe problems in another, researchers have reported that an LLD surpassing 2 cm (roughly 3/4 inch) leads to significant gait asymmetry.<sup>8</sup> In practical terms, such asymmetries mean that the longer leg bears more weight for more time, with



Structural leg-length discrepancies usually affect gait differently than functional ones; assessing the movement of the patient's center of mass can help differentiate them.

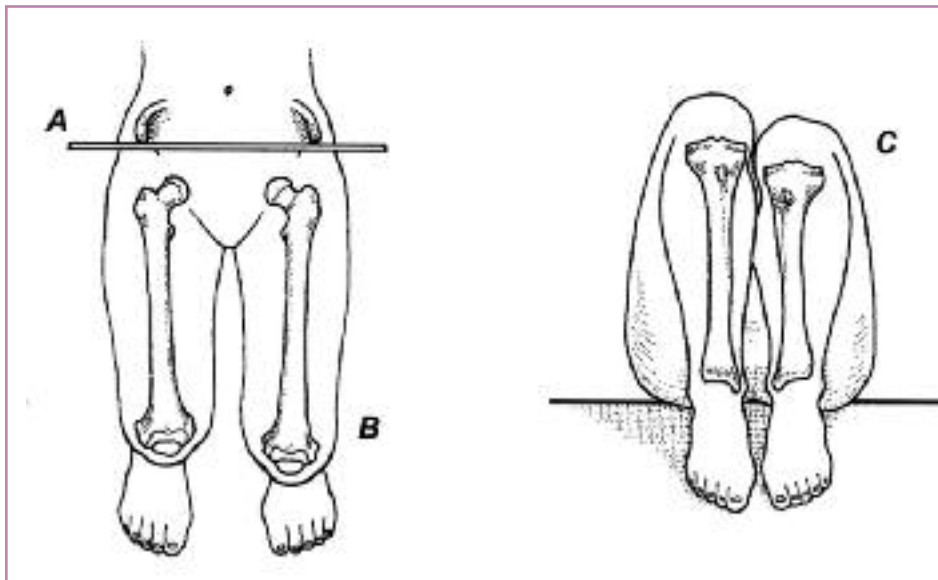


Figure 1. Allis test. The examiner manually aligns the ASIS (anterior superior iliac spine) of each limb so that they rest on the same frontal and transverse planes. The medial malleoli are then placed together, and femoral lengths are evaluated from above (left), while tibial lengths are determined by comparing the levels of the tibial plateaus (right). (Reprinted with permission from reference 10.)

cumulative effects that may include increased risk of hip or knee osteoarthritis.<sup>3</sup> Because of the potential for such negative outcomes, some clinicians intervene when LLDs are as small as 1/8 inch, particularly if the patient is an athlete.<sup>2</sup>

People with LLDs tend to compensate with tactics that help equalize functional leg length and minimize the excursion of the center of gravity, hence reducing energy cost; these include holding the foot in some degree of equinus on the shorter side, short-side pelvic drop, flexion of the knee or pronation of the foot on the longer side, or supination of the foot on the shorter side.<sup>3</sup>

## Assessment

Assessment of LLDs and their effects is complicated, partly because there's more than one type of discrepancy. Structural LLDs involve a femur or tibia that is literally shorter on one side than the other; this often leads to a tilted pelvis and related spinal complications such as scoliosis. Functional LLDs often result from pelvic obliquity related to muscle contractures or other causes; as the pelvis rotates, the legs are pulled into different apparent lengths even if the actual lengths of the bones are equal.<sup>2</sup>

Moreover, some LLDs result from a combination of structural and functional causes. One way to distinguish causative factors is to seat the patient; if the LLD is causing the scoliosis, the latter will disappear. If the scoliosis or pelvic obliquity is causing the LLD, by contrast, it will persist when the patient sits.<sup>2</sup>

Structural LLDs can have multiple causes, according to Anil Bhavé, PT, director of

the Wasserman Gait Laboratory at the Rubin Institute for Advanced Orthopedics in Baltimore, MD.

"A child may be born with a congenital discrepancy," Bhavé said. "Growth may also be arrested due to infection or injury, which constitutes a developmental discrepancy. Finally, post-traumatic discrepancies occur when the bone shortens due to a fracture."

Elaine Owen, MSc, MCSP, a pediatric physical therapist at the Child Development Center in Bangor, North Wales, UK, works primarily with children who have cerebral palsy (CP), spina bifida, and other hereditary disorders including sensory motor neuropathies, all of which may lead to LLDs. Such kids seem particularly susceptible to the developmental issues associated with neurological pathology.

"The trick is to find out what, exactly, is short," Owen said. "Some children will have a short femur, a short shank, or both—sometimes with scoliosis, sometimes without. Children with these disabilities can't compensate the way neurologically intact adults do. If you're grown, and you have a hip replacement or a traumatic accident, one limb may become short, but neurologically you're sound; you may use compensations such as pelvic obliquity to equalize the leg-length discrepancy.

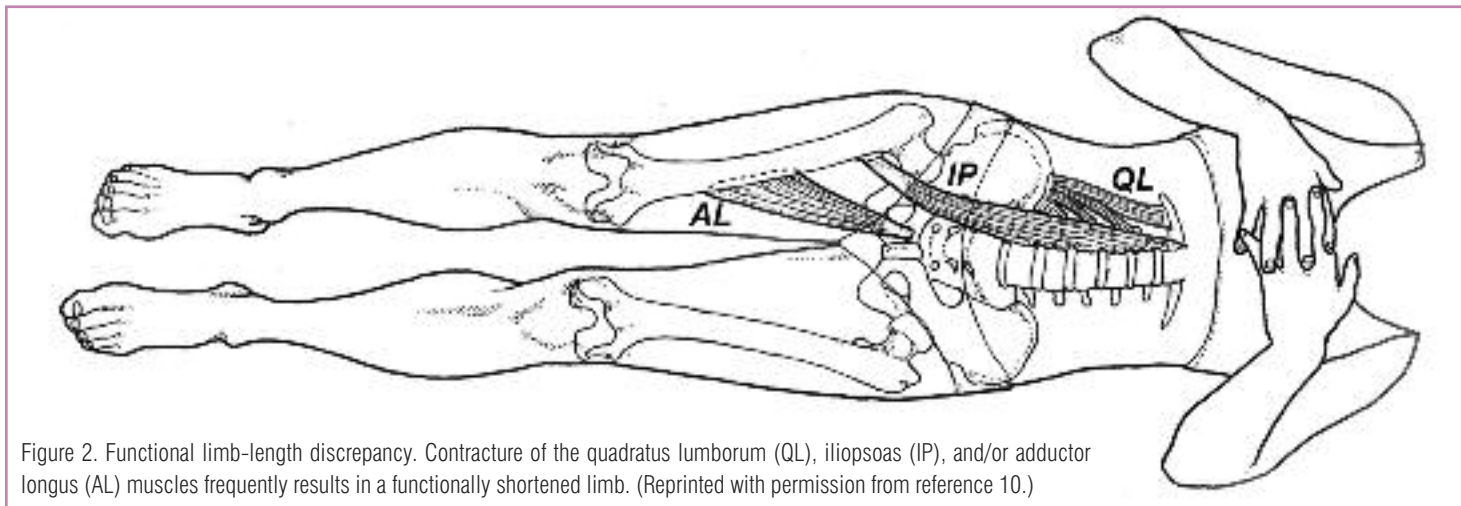


Figure 2. Functional limb-length discrepancy. Contracture of the quadratus lumborum (QL), iliopsoas (IP), and/or adductor longus (AL) muscles frequently results in a functionally shortened limb. (Reprinted with permission from reference 10.)

Continued on page 50



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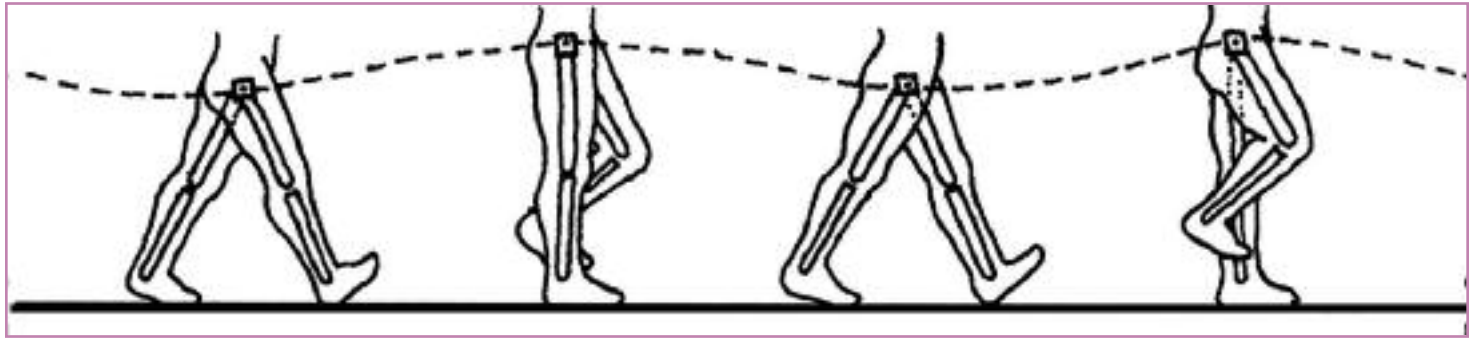


Figure 3. Pelvic rotation as a determinant of gait. A lateral view of the gait cycle with the knees and hips locked illustrates how the pathway of the center of mass creates an exaggerated sine wave, which is metabolically expensive because the hip abductors must raise and lower the center of mass through the exaggerated ranges. This type of sine wave pattern is more characteristic of a structural limb-length discrepancy than a functional one. (Adapted with permission from reference 10.)

But, for children with disabilities, these compensations—knee flexing, pronating, supinating, making ground contact with an equinus foot instead of with the heel—are big problems. The debate is about when to intervene.”

Research has described some of the problems that particularly afflict children with CP. In one study, for example, the authors reported both an increased pelvic tilt range and pelvic retraction in roughly 61% of patients, and noted that factors such as LLD contributed to the deviations. They recommended that evaluation of gait abnormalities in such children should not be limited to sagittal plane kinematics but should include 3D kinematics of the pelvis as well.<sup>9</sup>

Tom Michaud, DC, a chiropractor in Newton, MA, who has written extensively about leg-length discrepancies,<sup>10</sup> has developed a practical assessment protocol (Figures 1 and 2) that works for most of his patients. To compare tibial lengths, he has the patient recline and put the medial malleoli together. Evaluating femoral length is more challenging, he said, because tightness in certain muscles such as the quadratus lumborum can affect pelvic tilt and apparent leg length.

There may also be issues in the ankle or foot.

“If I identify a tibial discrepancy, I’ll do a standing test and compare the heights of the medial malleoli,” he explained. “If one is lower to the ground, then I know there’s a subtalar or midtarsal component.”

Michaud said that to distinguish structural from functional LLDs he often assumes a functional discrepancy and assesses the patient’s response to stretching.

“I have them stretch the quadratus lumborum, stretch the abductors, stretch asymmetric muscle tension and see if that reduces the discrepancy,” he said. “You may also notice that almost all people with an LLD prefer to stand with more weight on the short leg, so I can note that while I’m getting their history.”

Michaud told *LER* that structural LLDs usually affect gait differently than functional ones, and assessing the movement of the patient’s center of mass can help distinguish the two (Figure 3).

“In a structural discrepancy, the center of mass goes high when the long leg is in midstance,” he said. “Then they drop down and will sometimes toe out on the short leg because they get a little lateral displacement of their center of mass. In a functional discrepancy, the soft tissues adapt, and you don’t see big fluctuations in the sine-wave motion of the pelvis.”

## When to treat

For Michaud, decisions about what patients to treat, and how, depend on several factors.

“If someone has a chronic pain pattern—say, long-leg hip abductor pain, chronic lumbosacral pain aggravated by walking but OK with sitting, or if they’re a runner, I’ll be much more likely to address even a small structural discrepancy of, say, four millimeters,” he explained.

Typically, Michaud will give patients a heel lift, then videotape them walking. In the best cases, he sees a smoothing of pelvic motion as the patient transitions from double- to single-limb support.

The decision to prescribe an orthosis versus a heel lift depends on similar biomechanical factors, Michaud said.

“If a dropped malleolus or an asymmetric pronation is producing the leg-length discrepancy, I use an orthotic,” he said.

To assess the midtarsal component of an LLD, he employs a method he has developed that measures the change in the horizontal position of the medial malleolus as the patient moves from a talonavicular-neutral position to relaxed calcaneal stance.<sup>10</sup>

“I look for asymmetry in that medial movement component,” Michaud said. “If there’s excessive motion, patients have more medial drift on that side.”

Michaud emphasized that he never treats functional LLDs with lifts or orthoses.

“In those cases, you mobilize them, stretch them, do some muscle work, and it disappears,” he said.

Indeed, another clinician has written that, when patients with functional LLDs and scoliosis sought chiropractic treatment, in many cases the scoliosis disappeared.<sup>2</sup>

For Elaine Owen’s children with CP and other pediatric patients, intervention in LLDs may involve surgery.

“In the UK, the threshold for surgical correction is usually two centimeters by the time they’re a teenager,” she said.

Consultants measure the discrepancy with a CT scan, then assess bone age with an x-ray (children with such conditions often have a bone age different than their chronological age). Once such measurements have been done, physicians calculate when and how to intervene.

“They usually do an epiphysiodesis—a stapling of the growth plates at either the distal or proximal end of the tibia or femur of the longer leg, to stop growth,” Owen said.

Continued on page 52



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There's been some debate over decisions only to partly correct LLDs in such pediatric patients, she explained, because some surgeons prefer to leave a leg with drop foot slightly shorter to help prevent tripping in swing phase.

"The issue is whether it's better to fully correct or not," Owen said. "A cerebral palsy child with hemiplegia may look like they have a drop foot, but sometimes it's just that they make initial ground contact at the end of the gait cycle with their toes. If you insert a wedge to compensate for leg length, they may make contact with their heel instead, because they were actually just trying to find the floor. So you have to consider whether you're dealing with genuine drop foot; if you equalize leg length, do they have enough dorsiflexion capability to make initial ground contact with the heel? If so, fully correcting the leg-length discrepancy may be a good idea, rather than leaving the leg with drop foot a bit short."

Equalizing leg lengths—whether surgically or with a heel wedge or orthosis—is important for such children for other reasons as well, including their unique compensation strategies, Owen explained.

"One common compensation is that in terminal stance they flex the longer leg to help find the floor. They can also overpronate the long leg and supinate the shorter one. So, when we have a child with a disability and a leg-length discrepancy of more than five millimeters, we almost always treat it with either footwear or AFOs [ankle foot orthoses]," she said. "Some people say you don't need to do that, but we've found that it makes a big difference in how they walk. We could be more analytical about who should have a leg-length discrepancy equalized rather than assuming that all initial contacts with a toe are due to a drop foot."

## Bone growth

Surgeons tend to be cautious about the degree of correction in such cases for a variety of reasons, however. Michael Sussman, MD, a pediatric orthopedic surgeon at Shriners' Hospital for Children in Portland, OR, told *LER* that his pediatric patients with leg-length discrepancies include those with CP, vascular malformations, growth-plate infections or fractures, trauma, or idiopathic causes.

"We do our best to project patients' bone growth, but such projections aren't perfect," Sussman said. "You certainly don't want to overcorrect anyone."

To measure patients' bone lengths, Sussman and his colleagues use a digital dual-plane x-ray system that provides better images at a lower dose of radiation than standard radiographs. He considers patients to be candidates for lengthening surgery if the projected leg-length discrepancy will be more than four or five centimeters.

"In other cases, we can stop growth in the longer leg at the growth plates at either the distal femur or the proximal tibia, or both," he said. "We now use screws [in the growth plates] instead of staples because you can do it through a tiny incision and they don't have to be removed."

Kristie Bjornson, PT, PhD, a pediatric physical therapist at Seattle Children's Research Institute, told *LER* that some pediatric orthopedic surgeons may balk at lengthening children's legs because they don't see the results of those decisions when the children grow up.

"If you have cerebral palsy, and you grow up walking around with an asymmetrical pelvis, you're putting stress on joints that are already stressed because of neuromuscular problems," Bjornson said. "You end up with asymmetries, back problems, and pain; so from my perspective, treating those kids is preventive medicine. You

don't need to add leg-length discrepancies to the challenges they already have with motor control. If you correct them—whether surgically or with lifts or orthoses—their gait symmetry improves, and if you improve symmetry you improve efficiency."

Surgeons performing leg-lengthening procedures—in adults, adolescents, and older children—have new tools at their disposal that, as they become more widespread, have the potential to significantly improve traditional fixation techniques. The old approach, known as Ilizarov distraction osteogenesis, involves wires attached to the bone from external fixators (the original wires were bicycle spokes, in fact). It's effective but painful, and it carries infection risks.

At Sinai Hospital in Baltimore, Chief of Orthopedics John Herzenberg, MD, uses a device (Figure 4) that consists of an adjustable intramedullary nail activated by an external magnet (see "Early outcomes support internal technique for limb lengthening," *LER: Pediatrics*, May 2014, page 7). (Herzenberg is an advisor to the manufacturer but receives no royalties.)

"The device is accurate, controllable, and reversible," Herzenberg said. "I typically program it for a millimeter of growth a day, but if you want to back up a little and let the bone take a rest, you can."

Although Herzenberg and his colleagues use the device in children as young as about 9 years, most of his patients are adults who have suffered traumatic injury or congenital deficiencies that were never treated. Not only does the approach reduce infection risk—no wires pierce the skin—the absence of external fixation makes physical therapy much easier, he said. Surgeons remove the intramedullary nail about a year after lengthening is complete, because the internal magnet would prevent future magnetic resonance imaging procedures if the patient needed them.

Herzenberg and his colleague, Anil Bhavé, have documented improvements in gait parameters after leg lengthening using older techniques. In 1999, they reported in the *Journal of Bone and Joint Surgery* that the procedure restored stance-time symmetry in 16 of 18 patients and offered other benefits, including back pain relief.<sup>3</sup>

## Restoration hardware

One source of leg-length discrepancy that's attracted the attention of clinicians is total hip arthroplasty (THA), partly because postoperative discrepancies are a significant cause of patient dissatisfaction and litigation.<sup>11</sup> According to the literature, the problem occurs after up to 27% of THAs.<sup>12</sup>

In many cases, LLDs that persist months after THA can be



Figure 4. An adjustable intramedullary nail activated by an external magnet (right) offers an alternative to external fixation (left) for surgical limb lengthening. (Photo courtesy of John Herzenberg, MD.)





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effectively managed with heel lifts or insoles; in one study, roughly two-thirds of patients with LLDs after THA found that orthotic devices were effective for symptom management.<sup>13</sup> But a surgeon's approach can go a long way toward minimizing the risk of these types of postoperative LLDs.

According to Peter Sculco, MD, attending surgeon in adult reconstruction and joint replacement at the Hospital for Special Surgery in New York, surgeons must take great care in measuring leg lengths while planning for a THA. True limb length is measured from the anterior superior iliac spine to the medial malleolus, whereas apparent length is measured from the umbilicus to the medial malleolus. The former measures just what it says it does; the latter considers factors that contribute to length discrepancies, such as pelvic tilt.<sup>14</sup>

"Everything starts with taking a good history," Sculco said. "You want to identify any risk factors for a leg-length discrepancy more than the cartilage the patient will have lost from having arthritis. That's usually about three millimeters, but most patients don't notice because it's happened so gradually over time, and that's what you're restoring when you do the reconstruction. Those other risks include pelvic obliquity that may result from either a soft-tissue contracture around the hip or from deformities in the lumbar spine."

Once the surgeon has taken the history and made such assessments, he or she compares these findings with radiography results, Sculco explained. Pelvic reference points include the inferior aspect of the obturator foramen, the ischial tuberosities, and the acetabular teardrop.<sup>14</sup>

"You measure that fixed point on the pelvis to one on the femur, usually the lesser trochanter," Sculco said. "You compare the two and get a radiographic difference in leg length, and hopefully that


matches what you see clinically. You can then start with your templating—how you want to restore leg length at the time of surgery."

Surgically restoring the true center of rotation of both the acetabulum and the femur should lead to restoration of the original limb length before there was arthritis-related cartilage loss, according to Sculco; that, rather than lengthening per se, is the goal.

"Let's say you have a functional leg-length discrepancy involving a pelvic tilt, a soft-tissue contracture, that makes the operative leg a centimeter shorter," Sculco said. "You don't go in and lengthen the leg to eliminate the functional discrepancy, because once you put in the new hip they're going to straighten out. They'll lose the flexion contracture, and their pelvis will normalize over time."

In the rare cases in which a patient has a fixed pelvic obliquity (eg, lumbar fusion) that will prevent the pelvis from naturally correcting postoperatively, surgeons may consider a planned lengthening of the leg, according to Sculco. There are other complicating factors to consider, however.

"You have to get the soft-tissue tension required for the hip not to dislocate," he said. "Dislocation is much more catastrophic than a couple of millimeters of discrepancy. But, if you have good x-rays, valid templating, and a solid plan for restoring leg length, you should be able to get within three millimeters ninety percent of the time."

As surgeons and other clinicians collaborate to achieve the best outcomes for the wide spectrum of patients with leg-length discrepancies, careful planning will ideally become the norm in both surgical and nonsurgical approaches to the problem, to the great benefit of patients. 


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

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

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
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OPTP has added the Posture Brick to its line of fitness and therapy products. Posture Bricks can be used for yoga or Pilates, or in clinical settings focused on positioning, posture, and therapeutic exercise. Posture Bricks are made from closed-cell, heat-molded EVA (ethylene vinyl acetate) foam for comfort and durability. In yoga, the brick can be used to achieve better form, balance, and alignment as flexibility progresses. In Pilates, the bricks can provide seating assistance to ease tension in the hips, lower back, and hamstrings. Posture Bricks are available in three sizes: 12" x 6" x 3", 18" x 10" x 2", and 18" x 10" x 3".

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Spenco Medical Corporation's new line of sandals and slides is characterized by summery stripes, bright colors, and a new width option. New to the Spenco footwear line are the Breeze open-toe slides and sandals for men and women and the Montauk closed-toe slide for women. Breeze styles, created for athletes in need of recovery footwear, feature breathable uppers, soft synthetic linings, and a slight heel lift. The Montauk features a striped upper made from washed cotton canvas for a vintage look. In addition, the Yumi and Knolo sandals now come in wide widths (black only) for both men and women.

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**Pro-Tec Athletics  
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New from Pro-Tec Athletics is the PF Sleeve, a low-profile, comfortable option for treating plantar fasciitis. The PF Sleeve features an open-toe design and advanced stitching designed to provide targeted stabilization for the arch, heel, and Achilles tendon. The PF Sleeve also features specialized compression zones for arch and heel support. Each sleeve is designed to fit either the left or right foot, and is available in three unisex sizes, corresponding to shoe sizes ranging from a women's 5 to a men's 14. Other Pro-Tec products for plantar fasciitis include arch supports, a soft splint, and a spiky massage ball.

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Össur has launched Rebound Hip, a comfortable, lightweight postoperative brace for patients recovering from hip arthroscopy, gluteus medius repair, or hamstring repair surgery. The universal belt fits hip circumferences up to 48", and an optional belt extender accommodates hip circumferences up to 67". The lightweight, universally-sized frame features a quick-fit sliding mechanism that allows clinicians to easily fit patients of varying heights. The Rebound Hip brace is available with or without a hinge that can easily be adjusted by the clinician to allow hip abduction/adduction between 0° and 10°, 20°, or 30°.

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Microfiber Shades  
In New Colors

Sigvaris North America is putting its best foot forward this summer with the launch of several additions to the Microfiber Shades line of graduated compression stockings. Designed to give people a fun, new way to wear compression every day, the Microfiber Shades line is now available in four striped patterns (dark navy, pink, onyx, and graphite) and in two levels of graduated compression (15-20 mm Hg and 20-30 mm Hg). The advanced microfiber technology of the Microfiber Shades line is designed to wick away moisture to keep feet dry and comfortable. The socks are suitable for work, travel, and daily wear.

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Orthozone introduces its Thermoskin Thermal Ankle Brace, designed to provide heat therapy and light compression to help increase circulation. Features of the brace include a pull-on design, antislip sole, and two removable side stabilizers for ankle support. The Trioxon lining includes a soft, comfortable inner layer that wicks away moisture, a middle layer that helps increase skin temperature, and an outer layer that provides light compression. Potential brace applications include arthritis, sports injuries, repetitive strain injuries, diabetes, weak ankles, and cold and sensitive feet. Available in sizes XS-XXL.

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The Caresox Diabetic Light Compression sock is designed to provide maximum comfort for patients with diabetes. Manufactured in Italy, the quick-drying Silver DryStat fibers are antifungal, antibacterial, and odor resistant. The light compression (10-15 mm Hg) helps improve circulation, stimulate blood flow vein return, and reduce foot and leg swelling. A woven arch support helps with Charcot neuroarthropathy and midtarsal degeneration. A soft, padded terry sole is designed to provide long-lasting comfort and help reduce the risk of microtrauma. A dual-tone design facilitates early visual detection of wounds.

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**CuraMedix OrthoPulse Ultra**

The OrthoPulse Ultra from CuraMedix is an acoustic pressure wave device that combines EPAT (Extracorporeal Pulse Activation Technology), innovation, and performance to help physicians eliminate their patients' musculoskeletal pain. The system includes a compressed air ballistic pulse wave generator, a D-Actor hand piece, and three applicators. EPAT is a noninvasive treatment method designed to help damaged tissue regenerate and heal. Benefits include no risk of infection, no scarring, and no downtime. The small footprint of OrthoPulse Ultra makes it mobile and easy to integrate.

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## NATA meeting research highlights mechanical effects of cleats, tape


Studies presented June 25 at the annual meeting of the National Athletic Trainers Association (NATA), held this year in Baltimore, reported on the effectiveness of the Under Armour high-top football cleats for controlling ankle inversion/eversion and on the adhesive properties of three brands of elastic therapeutic tape.

Investigators from the University of Delaware in Newark compared ankle joint laxity and postural control in 32 interscholastic football players while they wore the Baltimore-based company's Highlight cleat or a mid/low-cut cleat and ankle tape applied to the nondominant ankle.

They measured balance and ankle inversion/eversion for the two conditions before and after a football practice. The mid/low-cut cleat with tape con-

dition had significantly higher inversion/eversion rotation postexercise compared with the Highlight cleat condition.

Researchers from the University of San Diego in California compared adhesion over five days among three brands of elastic therapeutic tape (ETT). They recruited 20 healthy volunteers, aged 18-65 years, and randomized them to receive simultaneous applications of two de-identified ETT brands on either side of their lower backs, collecting digital photograph data at one hour, three days, and five days.


The evaluators, who demonstrated a high degree of interrater reliability, found that Akron, OH-based TheraBand's tape provided significantly better adhesion over five days compared with the other brands. 

## NATA opens injury prevention website

The National Athletic Trainers Association (NATA) in June at its annual meeting in Baltimore announced the launch of a new website, [atyourownrisk.org](http://atyourownrisk.org).

This site promotes NATA's public awareness campaign designed to educate, provide resources, and equip the public to act and advocate for safety

in work, life, and sport.


The site includes pertinent information for parents, student athletes, school administrators, employers, legislators, and others on the benefits of sports and physical activity and how athletic trainers can play a substantial role in mitigating risk. 

## ISPO reports on disability rehab outreach

The International Society for Prosthetics and Orthotics (ISPO) in March published the final report on its joint program with the US Agency for International Development (USAID) on disability rehabilitation in the developing world.

The ISPO-USAID report, "Rehabilitation of people with physical disabilities in developing countries," details the program's successful activities, which include 112 candidates from 34 countries in its schol-


arship program completing their study to become prosthetists, orthotists, and orthopedic technologists (a 95% student progression rate due to rigorous selection criteria); measuring the impact of its programs in 13 countries; and progress in collaboration with the World Health Organization (WHO) on the first WHO Standards for Prosthetics and Orthotics Service Provision.

Download the full report at [ispoint.org](http://ispoint.org). 

## Orthotist-prosthetist Newberry dies

James Newberry Jr, BOC, BOCO, BOCPD, a practitioner and board member for the Board of Certification/Accreditation (BOC) died June 27. He worked for more than 40 years at Mahanke's Orthotics Prosthetics in Oakland Park, FL, where he was a practitioner, owner, and, most recently, director of orthotics/prosthetics.

Newberry served the BOC in numerous capacities, including chair of its Board of Directors and interim executive director.


He was also a facility accreditation site surveyor, a video practical exam reviewer, and a test development volunteer for the BOC's orthotist, prosthetist, and pedorthist exams. 

## GlobalData predicts slow joint surgery mkt

London, UK-based GlobalData on June 29 forecasted slow expansion through 2022 for the global hip and knee reconstruction market, which encompasses 39 countries and includes primary, partial, and revision hip and knee replacements, as well as hip resurfacing.

Sluggish growth will see the market increase at a compound

annual growth rate of 2.5%, from just under \$14 billion in 2015 to \$16.46 billion by 2022, according to the research and consulting firm.


Austerity measures in Europe, the medical device excise tax in the US, and deferrals of elective surgeries will stunt market growth, according to GlobalData. 

## West is Redskins sports medicine director

The Washington Redskins on June 15 announced that Robin West, MD, is the team's new director of sports medicine, which also makes her the first female head team physician in the National Football League.

West, a board-certified orthopedics and sports medicine surgeon, is medical director of Inova Sports Medicine in Fairfax, VA, and was the first

female physician in the Major Baseball League, serving as lead doctor for the Washington Nationals.

She was previously assistant orthopedic team physician for the Pittsburgh Steelers for 11 years and team physician for the athletic departments of Carnegie Mellon University in Pittsburgh and the University of Pittsburgh. 

## NYSCF opens access to stem cell lines


The New York Stem Cell Foundation (NYSCF) Research Institute and the Charcot-Marie-Tooth Association (CMTA) in June announced the stem cell lines resulting from their collaboration, which began in 2014, are now available to academic and commercial investigators around the world through the NYSCF Repository.

The CMTA coordinated 19 patients with a number of CMT diseases who provided fibroblasts to NYSCF scientists, who

induced pluripotent stem cell lines using the foundation's automated Global Stem Cell Array.

Eleven lines are currently available; the remaining eight lines are undergoing reprogramming.

The stem cell lines available are the largest collection of lines for a variety of neuropathy disorders of known genetic causation, according to a release from the organizations.

Visit [nyscf.org/repository](http://nyscf.org/repository) to order stem cell lines. 

## Arizona AFO introduces Mezzo brace

Arizona AFO, an OHI company, in late May introduced the Arizona Mezzo ankle foot orthosis (AFO). Developed by the Milwaukee, WI-based Wilson Janisse Group, the Arizona Mezzo was designed to fill the middle ground between the limited function of a UCBL (University of

California Biomechanics Lab) orthosis and the control of an Arizona Brace, the namesake of the Mesa, AZ-based company.

Dennis Janisse, CPed, a principal in Wilson Janisse Group and director of pedorthics for OHI, led development of the product. (ler)

## FDA gives Cartiva implant premarket OK

Alpharetta, GA-based Cartiva reported in July that the Food and Drug Administration (FDA) has given premarket approval to its biocompatible cartilage implant designed to treat hallux rigidus. The FDA based its preliminary approval of Cartiva SCI (synthetic

cartilage implant) on results from a 236-person randomized clinical trial comparing the implant with fusion; after two years the success rates for the implant and fusion were 80% and 79%, respectively, for the composite endpoint of pain, function, and safety. (ler)

## NIDDK funds study of off-loading AFO

Orthotic & Prosthetic Design and the Program in Physical Therapy at the Washington University School of Medicine, both in St. Louis, MO, reported in June that the National Institute of Diabetes and Digestive and Kidney Diseases has awarded university investigators a \$185,000 grant to develop an off-loading

carbon composite ankle foot orthosis (AFO).

Early testing at the university found 70% plantar pressure off-loading with the prototype AFO. The group will spend the next year developing, testing, and refining carbon composite brace designs. (ler)

## Siren Care to market smart diabetes sock

San Francisco-based Siren Care has partnered with Pasindu Lugoda, a PhD student at the University of Nottingham Trent in the UK, and his colleagues in the university's Advanced Textiles Research Group to bring to market a smart sock to help prevent amputation in people with diabetes.

Lugoda, a Sri Lankan with full scholarship in the PhD program, for his dissertation was

working on incorporating sensors into yarn to detect temperature changes on the foot that could indicate a diabetic foot ulcer.

Siren Care is taking pre-orders for the socks, which are washable because the sensors are encapsulated in water-resistant resin pods, on its website, [siren.care](http://siren.care), and reports the product will be available for shipping in September 2017. (ler)

## Diabetes event to include DFU workshop

The 9th World Congress on Prevention of Diabetes and Its Complications, scheduled for December 2-4 in Atlanta, GA, will include a separate two-day Diabetic Foot Workshop sponsored by the online Center for Diabetes Educa-

tion ([onlinediabetes.net](http://onlinediabetes.net)).

Register for the workshop, which will explore diagnostic and interventional strategies for diabetic foot ulcers and amputation prevention, at the World Congress site, [wcpd9.com](http://wcpd9.com). (ler)

## Medi's restiffic wrap provides RLS relief

A pilot study published in the July issue of *The Journal of the American Osteopathic Association* found that Medi USA's newly released device for treating restless leg syndrome (RLS) is associated with significant symptom relief.

Investigators from the Lake Erie Research Institute in Pennsylvania measured the response of 30 volunteers with moderate to severe RLS to eight weeks of wearing the restiffic adjustable compres-

sive foot wrap, which provides targeted pressure to the abductor hallucis and the flexor hallucis brevis. The wrap, which the Whitsett, NC-based company launched in June, reduced symptoms by 90%.

Researchers, who noted the wrap avoids the significant negative drug effects of current medications, wrote that pressure produced by the device may stimulate a dopamine release, similar to massage therapy or acupressure. (ler)

## Study finds need for adaptive apparel

Researchers from the University of Missouri in Columbia reported in June in *Disability and Rehabilitation* that the lack of adequate accessible apparel keeps people with disabilities from engaging in their communities.

They analyzed interviews from a focus group of disabled individuals and found apparel-related barriers fell into three basic categories: mechanical and functional barriers, cultural

barriers, and sensory sensitivity barriers.

"In many cases, the only options are custom-made clothing, which is not accessible due to high costs. Affordable clothes that can be mass produced are necessary to address specific apparel-related barriers identified in our research," said lead investigator Allison Kabel, PhD, assistant professor of health sciences. (ler)

## Ottobock releases socket technology

Austin, TX-based Ottobock in June released in the US the DVS-Dynamic Vacuum, transtibial socket technology that reduces movement between the limb and socket associated with limb volume fluctuations.

By generating a vacuum within the socket during walking,

the DVS maintains a level of elevation in swing and stance phases.

Developed for easy fabrication, fittings are simplified for integration of the system into the socket for both the patient and prosthetist, according to an Ottobock release. (ler)

## Tekscan taps Podoloff as chief tech officer

Boston-based Tekscan in June announced the appointment of Rob Podoloff, MS, as its new chief technology officer (CTO). Podoloff in the late 1980s was one of the company's original founders.

He's evaluating developments in nanomaterials and low-power processing, and plans to build on the existing flagship products at Tekscan,

many of which he developed, including the F-Scan in-shoe plantar pressure measurement device.

Podoloff is also a lecturer/lab instructor in mechanical engineering at the Massachusetts Institute of Technology in Cambridge, where he earned his undergraduate and MS degrees. (ler)



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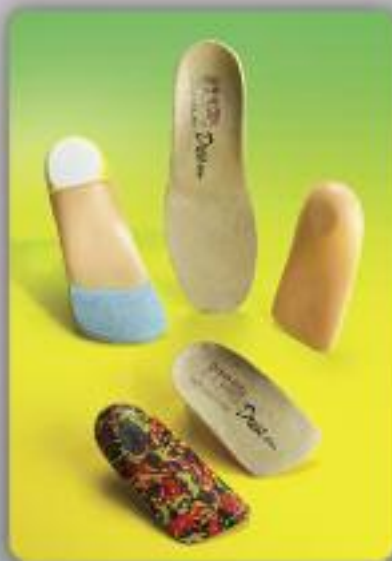
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