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LOWER EXTREMITY REVIEW

May 17 / volume 9 / number 5

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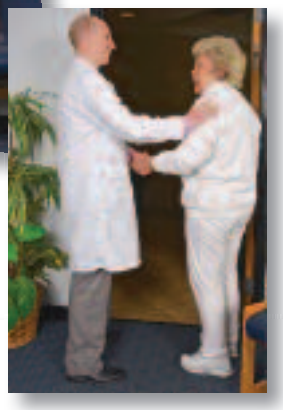

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Lower Extremity Review

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May 2017

VOLUME 9 NUMBER 5 LERMAGAZINE.COM

features

18 COVER STORY

Stepping up:

ORTHOTIC DEVICES HELP PATIENTS BOOST PHYSICAL ACTIVITY LEVELS

Improved mobility with ankle foot orthoses and other devices can help patients experience the multiple health benefits of increased physical activity. But aggressive activity goals—including the oft-cited target of 10,000 steps per day—may still be problematic for some device users.

By Larry Hand

IN THE MOMENT

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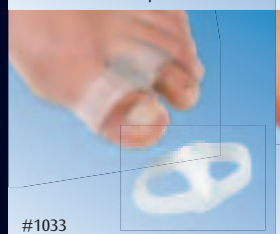
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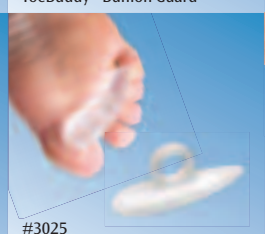
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Lower Extremity Review informs healthcare practitioners on current developments in the diagnosis, treatment, and prevention of lower extremity injuries. LER encourages a collaborative multidisciplinary clinical approach with an emphasis on functional outcomes and evidence-based medicine. LER is published monthly, with the exception of a combined November/ December issue and an additional special issue in December, by Lower Extremity Review, LLC.

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out on a limb:
Healing arts

Healthcare practitioners and artists wouldn't seem to have much in common, other than perhaps an appreciation of anatomy. But a new book has made me think the two professions also share an appreciation of people.

I'm no expert on art, and I hadn't heard of Andrew Wyeth's famous painting "Christina's World" until coming across a study in the medical literature suggesting that the woman who posed for the painting, previously thought to have been a polio survivor, instead seems likely to have had Charcot-Marie-Tooth disease. So I was intrigued that Christina Baker Kline (best known for her historical novel *Orphan Train*) chose to focus her latest novel on Wyeth's muse, Christina Olson.

A Piece of the World follows Wyeth's Christina as her upper and lower extremity function deteriorates throughout her life; by the time she poses for Wyeth in 1948, she cannot walk at all but continues to maintain the Maine farmhouse where she lives with her brother by pushing herself around on all fours.

Wyeth had considered a career in medicine before turning to art, but in the book, his interest in Christina has less to do with the clinical aspects of her impairments and more to do with how her experiences have shaped her as a person.

"I think you're used to being observed but not really…seen," he tells her. "People are always concerned about you, worried about you, watching to see how you're getting on. Well-meaning of course, but—intrusive. And I think you've figured out how to deflect their concern, or pity, or whatever it is, by carrying yourself in this dignified, aloof way."

Sound familiar?

The painting shows Christina lying—not quite comfortably—on a blanket in the field behind the rustic farmhouse. Christina was in her 50s when she posed for the painting, but Wyeth chose to depict her as a young woman. In the book, he reminds Christina that she once told him she sees her true self not as an invalid, a burden, a dutiful daughter—but as a girl.

Kline writes: *There she is, that girl, on a planet of grass … What she wants most—what she truly yearns for—is what any of us want: to be seen. And look. She is.*

Christina Olson was born too soon to benefit from the advances in orthotic technology, physical therapy, and surgery that are available to modern-day patients. A horrific experience with clamp braces as a young girl made her wary of doctors for the rest of her life.

> Like Christina Olson, your patients want to be seen. And you don't have to be an artist like Andrew Wyeth to make that happen.

But her story is a reminder that therapeutic interventions aren't all that lower extremity clinicians have to offer patients. Your patients—especially those who have struggled for years with chronic impairments—don't just want to be realigned and offloaded and strengthened and straightened. And they definitely don't want to be pitied.

Your patients want what Christina Olson wanted, what Andrew Wyeth was able to give her that no doctor ever was. They want to be seen. And you don't have to be a famous artist to make that happen.

Jordana Bieze Foster, *Editor*

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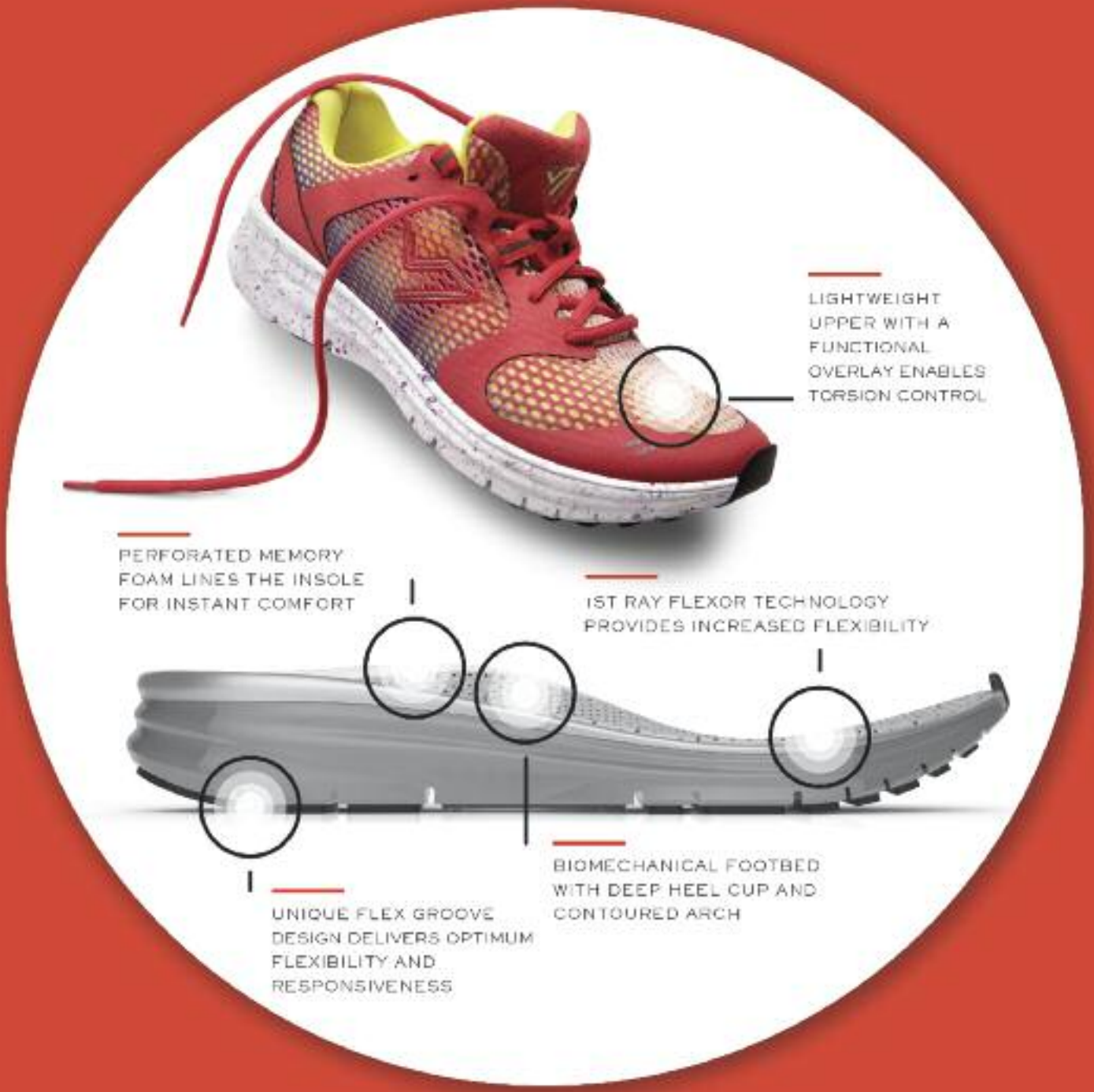

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Benefits of blood flow

Effect may facilitate Achilles healing

By Katie Bell

Microcirculatory blood flow two weeks after Achilles tendon repair is correlated with long-term patient-reported and functional outcomes, according to research from Sweden in which blood flow in both the injured and contralateral tendons was associated with healing potential.


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"The collective observations from our study support the conception that higher resting 'flux' [rate of blood flow] in the uninjured Achilles tendon is a reflection of tendinopathy, which is a general disease also occurring in the contralateral tendon and which is associated with inferior outcome after Achilles tendon rupture. It suggests that rehab should focus on both limbs," said corresponding author Paul Ackermann, MD, PhD, associate professor and specialist in orthopedic surgery at Karolinska University Hospital in Stockholm.

The study analyzed nine men (mean age 36.6 years) who were part of a larger study that examined the prevalence and prevention of deep venous thrombosis after unilateral Achilles rupture. All nine participants underwent surgery within 72 hours of injury; most were "weekend warriors," Ackermann said.

After surgical repair of the tendon, the patients underwent two weeks of postoperative rehabilitation; five were part of a group randomized to receive intermittent pneumatic calf compression beneath a weightbearing orthotic device, while four received nonweightbearing plaster cast treatment. At two weeks postsurgery, laser Doppler

Continued on page 14

Visual feedback on ground contact time helps improve performance in runners

Visual-augmented feedback-based training focused on reducing ground contact time is associated with improved performance in trained distance runners, according to a Swiss study.

Researchers from the Swiss Federal Institute of Sport Magglingen analyzed 30 trained male distance runners, each assigned to one of three four-week training conditions. An intervention group received visual augmented feedback as well as instructions, both focused on reducing ground contact time, during eight high-intensity training sessions. One control group trained with the intervention group but received no augmented feedback. A second control group did their own high-intensity training routine.

After the training, the runners in the intervention group demonstrated significant improvement compared with baseline for time on the ground per minute as well as mean 10 x 400-m performance time. Neither outcome changed significantly compared with baseline for the runners in either of the control groups.

The findings were published in early May by the *International Journal of Sports Physiology and Performance*.

–Jordana Bieze Foster

Source:

Gilgen-Ammann R, Wyss T, Troesch S, et al. Positive effects of augmented feedback to reduce time on ground in well-trained runners. Int J Sports Phys Perf 2017 May 1. [Epub ahead of print]

ACLR patients exhibit hop test deficits between limbs and vs matched controls

After anterior cruciate ligament reconstruction (ACLR), hop test scores differ not only between limbs but also when scores for either limb are compared with normative data from healthy athletes, according to research from the Netherlands that could have return-to-sports implications.

In 52 patients (14 women) a mean of seven months after ACLR, investigators from the University of Groningen assessed performance for each limb on three hop tests: single-leg hop for distance (SLH), triple-leg hop for distance (TLH), and side hop (SH).

For the group overall, scores differed significantly between limbs for all three tests. In the female patients, significant between-limb asymmetry was found only for the SLH test. Scores for both the involved and uninvolved limbs of the ACLR patients differed significantly from those of matched healthy athletes for the SLH and TLH tests. SH test scores differed significantly between the controls and the involved limbs of the male ACLR patients.

The findings were published in April by *Orthopedics & Traumatology: Surgery & Research*.

–Jordana Bieze Foster

Source:

Gokeler A, Welling W, Benjaminse A, et al. A critical analysis of limb symmetry indices of hop tests in athletes after anterior cruciate ligament reconstruction: a case control study. Orthop Traumatol Surg Res 2017 Apr 17. [Epub ahead of print]

Continued from page 13

flowmetry was used to assess microvascular blood flow in the midportion of the Achilles tendon bilaterally, during postocclusive reactive hyperemia.

"At two weeks, all patients returned for follow-up and were mobilized with an orthosis and were instructed to start bearing their full weight. At six weeks, the brace was removed," Ackermann said.

At three months postoperatively, patient-reported outcomes were assessed using the Achilles tendon Total Rupture Score (ATRS). At one year, the Achilles Combined Outcome Score (ACOS) was obtained by combining validated, independent, patient-reported ATRS and functional outcome (heel-rise test) measures. All nine patients were analyzed as one group.

A better ACOS outcome at one year was significantly correlated with higher maximum blood flow in the injured Achilles tendon. Additionally, a better ATRS outcome at three months was significantly correlated with an elevated ratio of maximum to resting blood flow in the uninjured Achilles tendon. The findings were epublished by the Scandinavian Journal of *Medicine & Science in Sports* in April.

Because physical activity influences microcirculation, the researchers looked specifically at patient characteristics that may affect physical activity (gender, age, body mass index [BMI], and smoking). Of these, age and BMI were the only variables that were significantly correlated with microcirculation.

Although the study did not assess the effects of different rehab protocols on blood flow or longer-term outcomes, "we believe that rehab can greatly influence microcirculation and thereby possibly healing," Ackermann said. "The best effects on leg blood flow that we have found thus far is to use intermittent pneumatic compression beneath a weightbearing orthotic device."

Karin Grävare Silbernagel, PT, ATC, PhD, an assistant professor in the Department of Physical Therapy at the University of Delaware in Newark, noted that the observed correlations in the Swedish study are likely related to the effects of weightbearing and loading during rehabilitation.

"I think blood circulation is of interest, but is probably related to activity, loading, or weightbearing status. It could be that the correlation found in the study is secondary to the two different treatments or weightbearing status and amount of weightbearing/loading that the patient has performed," Silbernagel said. "What we know today is that tendons need mechanical loading for healing. However, we do not know how that optimal loading should look."

However, Silbernagel said the rehab protocol she uses for patients who have had Achilles repair does include a vascular component.

"I use compression socks for all my patients to avoid swelling so the Achilles tendon has the best healing environment, which would include having good circulation," she said. ler

Sources:

Praxitelous P, Edman G, Ackermann PW. Microcirculation after Achilles tendon rupture correlates with functional and patient-reported outcome. Scand J Med Sci Sports 2017 Apr 4. [Epub ahead of print]

Domeij-Arverud E, Labruto F, Latifi A, et al. Intermittent pneumatic compression reduces the risk of deep vein thrombosis during post-operative lower limb immobilisation: a prospective randomised trial of acute ruptures of the Achilles tendon. J Bone Joint Surg 2015;97-B(5):675-680.

Alternating recurrence

Subsequent ulcers often occur in new sites

By Stephanie Kramer

Most practitioners are aware that diabetic foot ulcers have a high recurrence rate, but might be surprised by findings epublished in April suggesting a relatively large number of subsequent ulcers occur at new locations, including the contralateral foot.


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Although other studies have investigated the likelihood of ulcer recurrence in patients with diabetes, the authors of the current study believe that clearly defining the term "recurrence" could help aid prevention.

"I was really surprised by the lack of a uniform definition in the literature," said lead author Hedvig Örneholm, MD, PhD, a resident in the Department of Orthopedics at Lund University in Sweden. "No one has defined what a 'new' ulcer is. The literature refers to ulcers as new, recurrent, or plantar ulcer without distinguishing location."

Researchers at Skane University Hospital and Lund University in Sweden analyzed the occurrence of subsequent ulcers in 617 diabetic patients with a healed forefoot ulcer who visited the hospital foot-care clinic between 1983 and 2012.

After the initial ulcer healed, clinicians fitted all patients with custom-made footwear for both feet and assessed them at 12 and 24 months for recurrent (defined as occurring at the same site as the initial ulcer) and other new ulcers. Patients were seen by an interdisciplinary team consisting of a diabetologist, orthopedic surgeon, diabetes nurse, orthotist, and chiropodist. They also received oral and written instructions for self-care.

Investigators collected data on the development, characteristics, and outcome of subsequent foot ulcers. During the two-year follow-up, 42% of patients developed a subsequent foot ulcer. Of these,

Continued on page 16

Shoe closure technique affects thermal stress response in at-risk individuals

Shoelace closure technique can affect plantar thermal stress response (TSR) in patients with diabetic peripheral neuropathy, according to a study from Baylor College of Medicine in Houston, TX, that has implications for foot ulcer prevention.

In 15 patients with diabetic neuropathy, researchers assessed plantar TSR for the left foot (shoe laced as the patient habitually would) and for three shoe-closure conditions on the right foot (laced tightly, laced loosely, and with a preset reel-clutch closure).

TSR for each condition was calculated from thermal images obtained after five minutes of acclimatization and after walking 200 steps.

Compared with the habitual lacing technique, plantar TSR was significantly higher for the loose and tight conditions (70% and 67% higher, respectively). Plantar TSR was significantly (206.5%) lower for the reel-clutch condition than patients' habitual lacing technique, which suggests a preset closure setting might be the best option for minimizing TSR in patients with diabetic neuropathy. The findings were epublished in April by the *Journal of Diabetes Science and Technology*.

–Jordana Bieze Foster

Source:

Rahemi H, Armstrong DG, Enriquez A, et al. Lace up for healthy feet: The impact of shoe closure on plantar stress response. J Diab Sci Tech 2017 Apr 18. [Epub ahead of print]

High neuropathy prevalence at rural free clinic underscores unmet need

The prevalence of diabetic peripheral neuropathy at a free clinic in rural South Carolina is significantly higher than averages reported in the literature, according to findings that underscore the need to improve diabetes education and foot care in underserved populations.

Investigators from the Presbyterian College School of Pharmacy in Clinton, SC, assessed the prevalence of diabetic neuropathy and painful diabetic neuropathy in 111 patients attending a free clinic for diabetes education at the school's Wellness Center.

More than two thirds (67%) of the patients had diabetic peripheral neuropathy—a much higher prevalence than previously reported values ranging from 28% to 48%. Of the diabetic neuropathy cases, only 29% were documented by a referring physician. Nearly one-quarter (23.4%) of the total study population had painful diabetic neuropathy; of these, only 46.2% were documented.

The findings, published in April by the *Journal of Pain Research*, suggest pharmacist-run free clinics could play a key role in identifying and educating patients with diabetic peripheral neuropathy in underserved rural populations.

–Jordana Bieze Foster

Source:

Pruitt J III, Moracho-Vilrriales C, Threatt T, et al. Identification, prevalence, and treatment of painful diabetic neuropathy in patients from a rural area in South Carolina. J Pain Res 2017; 10:833-843.

Continued from page 15

8% developed a foot ulcer at the same site, while 34% developed one elsewhere (112 on the same foot, 99 on the contralateral foot). The patients who died during the two-year follow-up period were analyzed separately; of those 87 patients, none had a recurrent ulcer, but 30 had developed ulcers in new locations—16 on the same foot as the initial ulcer and 14 on the contralateral foot.

Risk of new ulceration was similar for patients whose initial ulcers required major surgical debridement or amputation prior to complete healing and those who healed without surgery. That finding contrasts with a 1998 Italian study in which patients treated nonsurgically developed new ulcers at the same site as the healed ulcer, while those treated surgically developed ulcers at new locations.

A smaller ulcer at baseline was associated with a lower risk of having a recurrent or new ulcer, Örneholm said. No other predictors were identified as having a significant association with ulcer development; however, the database was not designed for such an analysis, she said.

Örneholm noted that inadvertent effects of offloading the initial ulcer might be a contributing factor.

"If you relieve pressure in one place, you might increase pressure in a new place," she said.

The researchers did not discuss other factors such as peak plantar pressure, pressure-time interval, or shear that might influence ulcer development. The findings were epublished in April 2017 by *Wound Repair and Regeneration*.

Jaap van Netten, PhD, who is a human movement scientist at Queensland University of Technology in Brisbane, Australia, said the high number of recurrent ulcers in different locations reported by the Swedish authors is surprising.

"The results are a signal that the first year is really important after an ulcer heals. An ulcer is not healed. It's in remission. It's basically waiting for a new ulcer to develop," van Netten said. "Your patients are in remission, with one out of two getting an ulcer within a year."

A critical analysis of risk factors would have been welcome, van Netten noted. Despite this limitation, van Netten said the study makes an important contribution, highlighting the challenges clinicians face in preventing recurrent foot ulcers.

"It makes it harder to predict where the next ulcer will occur," van Netten said.

Patients themselves tend to be more focused on the primary ulcer location, he continued.

"I think the study is really a message to clinicians and patients that they should look at both feet every day and not focus on the previous ulcer location," van Netten said. "As a clinician, you cannot focus on the previous location alone. You must take a holistic look at the patient." ler

Sources:

Örneholm H, Apelqvist J, Larsson J, et al. Recurrent and other new foot ulcers after healed plantar forefoot diabetic ulcer. Wound Repair Regen 2017 Apr 1. [Epub ahead of print]

Piaggesi A, Schipani E, Campi F, et al. Conservative surgical approach versus nonsurgical management for diabetic neuropathic foot ulcers: a randomized trial. Diabet Med 1998;15(5):412-417.

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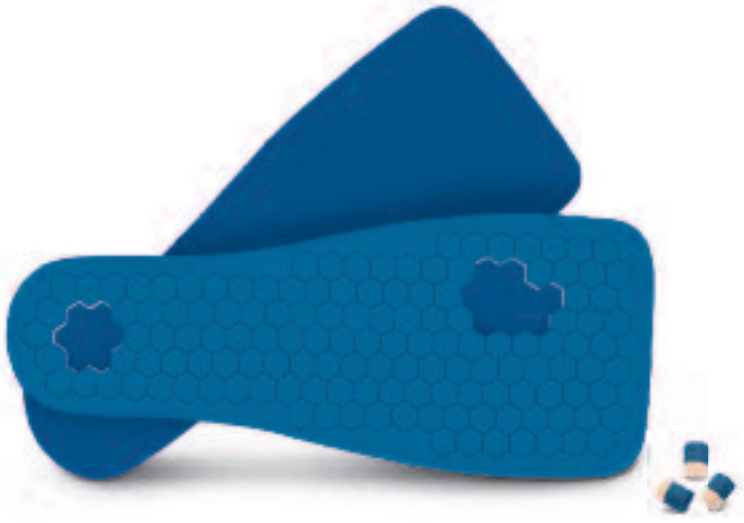

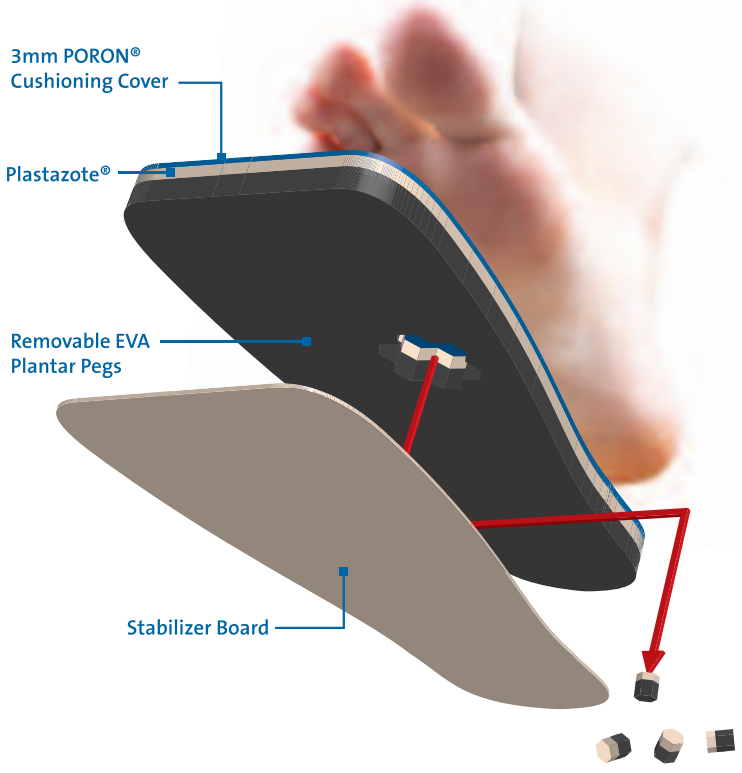

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Orthotic devices help patients boost physical activity levels

By Larry Hand

Improved mobility with ankle foot orthoses and other devices can help patients experience the multiple health benefits of increased physical activity. But aggressive activity goals—including the oft-cited target of 10,000 steps per day—may still be problematic for some device users.

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Meeting benchmarks in physical activity guidelines is difficult enough for some able-bodied individuals, but it can be an even bigger challenge for people who require orthotic devices to improve mobility.

In 2008, the US Department of Health and Human Services (HHS) issued its Physical Activity Guidelines for Americans.[1] The guidelines include:

- For children and adolescents, at least 60 minutes of moderate- or vigorous-intensity physical activity per day;
- For adults, 150 minutes per week of moderate-intensity physical activity or 75 minutes of vigorous-intensity physical activity;
- For older adults, as much physical activity as their health allows; and
- For adults with disabilities "who are able," 150 minutes a week of moderate-intensity or 75 minutes of vigorous-intensity physical activity.

Although not a specific guideline, the popular recommendation of taking 10,000 steps a day is mentioned in the document as a target that can help individuals comply with the guidelines, if the walking is brisk enough.

Orthotic device users, however, often face challenges in meeting these recommendations, in relation to both the duration and intensity of physical activity, and some lower extremity clinicians say a stepped approach is needed when prescribing physical activity in this patient population. Some also say guidelines should be adaptive for individuals with disabilities.

James H. Rimmer, PhD, director of the University of Alabama at Birmingham Lakeshore Research Collaborative and director of the National Center on Health Physical Activity and Disability, was involved in writing the 2008 guidelines.

Continued from page 19

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"In the report we basically said that, provided the right screening from the physician, people with a disability should be included in the guidelines. How they get there in terms of achieving them, that's a real challenge because there are so many variables associated with the environment and also barriers associated with the individual who may have certain limitations," Rimmer said. "Exercise instructors and clinicians often do not have the evidence or knowledge to prescribe the most appropriate and beneficial exercise for people with disabilities."

The recommendations the HHS and others have outlined, though relevant, are not necessarily attainable for people who are extremely deconditioned and highly sedentary, said Mark D. Peterson, PhD, MS, an assistant professor in the Department of Physical Medicine and Rehabilitation at the University of Michigan in Ann Arbor.

"We need to take a step back and look at what a person is doing and then find ways that we can introduce some activity in small doses that the person can achieve. And then over time we highly recommend that people continue to progress if possible, but attaining more of a minimalist perspective instead of a maximalist perspective in exercise," Peterson said.

Peterson was a coauthor of a 2016 article[2] that recommended exercise prescriptions for individuals with cerebral palsy should begin with a "familiarization" period of low-dose training twice a week for two to four weeks.

"Even in the typically developed population, a lot of people don't do a lot of physical activity. It may be because we are promoting extremely high volumes and higher intensities of exercise that are not palatable to most individuals," Peterson added.

Rational numbers

Christopher Kevin Wong, PT, PhD, OCS, associate director of the Program in Physical Therapy at Columbia University Medical Center in New York City, told *LER* he thinks keeping track of step counts is a good approach to trying to meet guidelines.

"I think ten thousand [steps per day] is reasonable" for many individuals, said Wong, who was the first author of a 2014 pilot study on relationships between foot orthosis use, physical activity, and functional level in obese patients.[3] "Sometimes in a group of more disabled patients, four thousand or six thousand might be appropriate."

In the pilot study, semicustom foot orthoses were prescribed based on arch index measures to obese women (mean body mass index [BMI] 42.4), who were also participating in a weight-loss program. After one year, eight of nine women said they wore the orthoses more than 50% of the time, and no adverse events occurred, which suggests the foot orthoses were safe and comfortable.

Wong and colleagues also found that changes in the ability to walk a mile were strongly correlated with changes in the rates of orthosis use and reductions in BMI, but, because the women were also in the weight-loss program, the exact contribution of orthoses could not be determined.

"From a biomechanical perspective, the idea was that many people who are obese may also have lower extremity alignment problems that might make it more difficult to be active. The concept of corrective foot orthoses, or biomechanical foot orthoses, is that if you were to correct them more, they would be able to do more," Wong said.

Continued on page 22

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Continued from page 20

Unrealistic physical activity goals can intimidate patients with disabilities who may feel they are being set up to fail, he said.

"You set up a goal, like exercise three times a week at thirty minutes a shot, and people can't really reach that because of life timing or because of their physical state," Wong said. "Then they feel like they're a failure or they feel like they can't do it and are never going to be able to do it, and as a result they don't do anything. I would prefer to have more reasonable, attainable goals. Then if you're able to do more, that's great."

More active, more engaged

Many of the benefits of physical activity for individuals with disabilities are similar to the benefits for their able-bodied counterparts.

"Exercise has one of the most profound benefits to a number of body systems—circulatory, cardiac, neurological, renal," Rimmer said. "You have to identify what system has a deficit, and then you have to create an exercise program to meet that deficit. When you talk about systems, you hear a lot about the cardiorespiratory system, which reduces your risk of heart attack and stroke. Strengthening activities involving the musculoskeletal system reduce your risk of fractures and injuries associated with falls. But most importantly, [physical activity] engages the individual in some sort of community-based network that provides enormous amounts of psychological well-being."

John T. Brinkmann, CPO/L, an assistant professor of physical medicine and rehabilitation with Northwestern University Prosthetics-Orthotics Center in Chicago, concurred.

"Individuals who experience disability often identify mobility and independence as their primary goals. However, people do not usually move for the sake of moving—we usually move because of a specific reason or with a specific purpose," Brinkmann said. "High levels of activity may allow individuals who are using an orthosis to participate in more activities and engage more with others in meaningful ways. It's this participation that is often the real motivation for developing an increased capacity for more intense or prolonged activity."

Proceed with caution

However, increasing physical activity is not always the right thing to do. Clinicians need to consider the diagnosis, physical presentation, and comorbidities of each individual patient when making recommendations regarding activity, Brinkmann said.

"In general, it's safe to say that more activity is better than less, but increased activity may increase the risk of injury for individuals with significant musculoskeletal injury or neurological deficit," he said. "Additionally, conditions that require orthotic management of the lower limb rarely occur in isolation—other body parts and systems are almost always affected. In many cases cognitive function must be considered, since an individual's ability to make sound decisions about their activity could be impaired. Assessing the individual's motivation is important as well. Pressuring individuals in the wrong way or at the wrong time may actually discourage activity. All of these factors should be considered when developing goals and guidelines for patients."

In some cases, there may actually be reasons not to encourage patients to exert themselves.

"If someone has a neurological problem related to diabetes and they need orthotic management, you have to be aware of the diabetes and possibly heart disease, so it's not the mobility problem alone in isolation, it's also their health in general," Brinkmann said. "In cases of severe functional deficits, exertion and fatigue can increase the risk of falls, so encouraging higher intensity activity may actually be counterproductive. Simply walking at a self-selected speed and performing common activities of daily living is a sufficiently advanced goal for many users of lower limb orthoses."

Generally, high levels of activity are less important than basic rehabilitation goals such as pain reduction, increasing strength, and improving balance, he said.

"The overall goal of rehabilitation is often an increase in basic mobility and independence, and in cases of extreme functional loss, high activity [as we normally think of it] is often not even an option," Brinkmann said. "Another way to look at this issue is that for many individuals with significant physical impairment, just walking at a normal speed requires a level of effort that is comparable to an able-bodied individual participating in a session of intense exercise.

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Continued on page 24

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Continued from page 22

For most of us, walking a normal speed does not constitute high activity, but for many of our patients it does."

Other clinicians agreed that, for certain patients, step-count goals may be counterproductive.

"There's a fair number of orthotic device users who are using those devices because of very specific pathology or impairment," said Christopher Neville, PT, PhD, an associate professor of physical therapy at State University of New York Upstate Medical University in Syracuse. "If their goal is to try and meet some sort of activity guideline or step count guideline, they could actually increase damage or further the progression of some dysfunction."

An important consideration for some patients may be the extent to which increasing physical activity is associated with pain, Neville said.

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"Patients need to increase their activity for the health benefits that come with that. However, they're doing that with increased pain, so then they feel like they have to limit that activity and let tissue heal and let joints recover," Neville said. "They've gotten into a cycle of decreased activity, so then how do they get out of this vicious cycle? Potentially, if they could increase their activity without further increasing pain or damaging tissue, that would be really beneficial."

In such patients, reducing activity in the short term can end up having long-term benefits, Wong said.

"Sometimes people feel like because they have challenges they should rest more and not do as much. I think that is a reasonable approach for a short-term period to become a little bit more capable," he said. "But in the long term, more is generally better. I tell my patients, 'If you want be able to get up from the toilet when you're eighty, you have to be more active.'"

Neville believes physical activity guidelines for individuals with disabilities should differ from those for able-bodied individuals, but he acknowledged the complexities involved.

"I'm not sure we can create a guideline that just becomes individually specified. Many orthotic device users likely need individualistic recommendations for activities," he said.

Benefits of orthotic devices

Orthotic devices, including ankle foot orthoses, can help individuals increase their physical activity levels.

Three of the most pertinent ways an orthotic device can help improve physical activity levels are by decreasing pain, improving mechanics, and changing sensory input, Neville said. Although clinicians typically think of orthotic devices impacting people in terms of function, those functional benefits can also translate to greater physical activity.

Orthotic devices can improve balance in many patients (see "Can AFOs help prevent falls?" August 2012, page 16), and may have other benefits that can help reduce the risk of falls, Rimmer said.

"You've got better alignment with the orthotic. It protects the bones. That protective factor allows one to feel more confident. It increases self-efficacy to exercise and [patients] have a more engaging experience, contingent upon not causing or reducing any type of injury or lasting pain," he said.

For orthotic devices to improve physical activity, comfort is key, Wong said.

"If people are more comfortable, they're more likely to do more activities," he said.

And clinicians should also keep in mind that increasing activity level can occur in ways that can't easily be quantified by a pedometer.

"One of the most rewarding things for any clinician is to hear their patient describing activities they are able to engage in as a result of the services the clinician has provided," Brinkmann said. "The most meaningful for me have been when patients describe their increased independence, ability to interact with family and friends in social settings, or ability to pursue work that is meaningful to them."

Does age matter?

Children can present challenges with regard to prescribing orthotic devices, but older age has its own considerations, particularly when it comes to making the transition from improved mobility to improved physical activity.

Some of the same issues that negatively impact physical activity in older adults can also make it more difficult to find an orthotic device that will help.

"Older adults have reduced overall mobility due to physiological changes in joint and soft tissue, as well as a greater number of medical conditions and [more] medication use," Neville said. "A practical example that might be helpful is that many older adults may have difficulty donning an orthotic device such as a lace-up ankle brace, thus impacting prescription."

Patient motivation can also be a factor.

"Probably the biggest difference is, generally speaking, with kids you're trying to keep up with them. If you ask any clinician in prosthetics and orthotics they'll say that kids are the hardest on their devices, because they're constantly pushing their activity to the limit of what is possible for them, and we have to design an orthotic system that will hold up to that," Brinkmann said. "With adults, the problem tends to be that we're trying to motivate them to a higher level."

However, he noted, age is just one of many factors—and not necessarily the most important one—to consider with regard to orthotic prescription and activity.

Continued on page 26

Continued from page 25

"The age of our adult patients is a factor to consider, but others have a much greater impact on function. Making assumptions based on age can result in inappropriate treatment recommendations, since these other, more important factors may be overlooked," Brinkmann said. "We can't assume that because someone is elderly they will function at a low level, or [perhaps more importantly] that a younger person's function will be higher."

Tracking progress

Interest has been increasing in tracking the progress of orthotic device users, according to clinicians, especially in wearable devices that count the number of steps taken.[4,5]

"Activity monitoring has been getting a lot of attention in research and clinical practice, because the benefits of having this information are obvious. Having hard data on step count and intensity is much better than simply relying on patient reports of activity," Brinkmann said.

However, Brinkmann and others noted many commercially available activity monitors are not accurate enough to track the subtle change in function common in many populations of lower limb orthosis users.

"One problem with some of the commercial step-count devices is they don't pick up very short steps that might be common in a disabled population, and they may not pick up very slow steps," Wong said. "Sometimes when the steps are not even, [this] can also confuse some of the commercial devices."

But Wong and Brinkmann both observed that activity monitoring technology is continually improving in ways that are likely to benefit orthotic device users.

"In coming years, I think we'll see significant advancements in these technologies that will enable clinicians to use them routinely to gather use and activity data," Brinkmann said.

Beyond fitness

In many ways, experts say, the challenges related to physical activity in orthotic device users are similar to those of the general population—challenges that all clinicians should be attempting to address with their patients.

One concern is that patients may be focusing too much on the guidelines for moderate- or vigorous-intensity activity, and not enough on increasing levels of low-intensity activity as well, Rimmer said.

"What we really need to do is be out and about more frequently. It's not just about thirty minutes of exercise in the morning and then sit for the rest of the day," he said. "We do need a good thirty minutes of fitness, but then we need to get another ninety minutes in during the day of just general activity: low-intensity, movement-based activities. We're woefully underselling and underutilizing the power of physical activity."

Those lower-intensity activities may prove to be where orthotic devices can really make a difference, Rimmer said.

"There's a biological benefit from moving regularly at certain intervals of the day, and that's where an orthotic can help," he said. "If a person feels safer and doesn't have any pain, it facilitates much greater use of that limb, and they're going to probably have an easier time reaching a low threshold of regular physical activity." ler

Larry Hand is a medical writer based in Massachusetts.

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National Biomechanics Day thrills kids worldwide

National Biomechanics Day continued to build momentum in its second year, as scientists from Delaware to New Zealand got a jump on recruiting the next generation of biomechanists by demonstrating a wide range of applications—not to mention just how much fun the field can be.

By Hank Black

The second annual National Biomechanics Day (NBD), officially held April 6, had an extended lifespan and a decidedly international feel. Around the world and throughout the month, thousands of elementary, high school, and undergraduate university students discovered the science of movement in its many manifestations, from gait analysis to acrobatic yoga to designing prosthetic devices.

In keeping with its slogan—"science meets fun"— NBD created widespread excitement among students, whose smiles appeared in myriad social media posts documenting their participation. Images and video featured in these posts included motion capture of soccer moves, fall prevention on a treadmill, advances in exoskeletons, making models of limbs, and competition to see who could jump on bubble wrap with the lowest number of popping sounds.

NBD memes bounced around the internet on Facebook, Instagram, Twitter (#NationalBiomechanicsDay on all), and other electronic platforms, many allowing real-time video and chatting to share activities. A few of the students' remarks: "This is amazing," "So much fun," and "I want to do this when I get to college."

"There are so many ways to use biomechanics in careers, but most students aren't introduced to the field before they make their decisions on what to study in higher education," said Paul DeVita, PhD, founder of NBD and past president of the American Society of Biomechanics (ASB). "We wanted to find a way to raise awareness and help young students discover this exciting field that can lead to so many different careers."

NBD has been able to capitalize on the immense popularity among young people of video games and animation, both of which intersect with biomechanics.

By the numbers

Last year's inaugural NBD attracted more than 2000 students at about 50 sites across the country. Some 175 biomechanists and graduate students participated.

This year, the number of students touched by the celebration exceeded 5000, with more to be counted in the US. They circulated through demonstrations at university and commercial laboratories in almost every state of the union. The events had a definite

Continued from page 29

At Sanford Sports Science Institute in Sioux Falls, SD, NBD events included a jump-off between kids and biomechanists. (Photos courtesy of Lisa N. McFadden, PhD.)

international flavor, as well, as multiple universities took part in New Zealand, Australia, Brazil, and England, and at least one site each in Saudi Arabia, Canada, Belgium, and other countries.

"The tremendous response has been gratifying to all who volunteered to participate," DeVita said.

The event's organizers hope to establish biomechanics as a standard element in high school curricula, said DeVita, who is a professor in the Department of Kinesiology and director of the Biomechanics Laboratory at East Carolina University in Greenville, NC.

"There will be more and more jobs available that involve biomechanics," he said. "Baseball teams have started to hire such specialists to help analyze the hitting and pitching movements of their minor leaguers. We biomechanists are working like crazy on the development of prosthetic devices for amputees. Exoskeletons, including those that power the lower extremities, fascinate many people."

At the University of Pretoria in South Africa, NBD activities took place both in the lab and on the field. (Photos courtesy of Helen Bayne, PhD.)

At the University of Memphis, high school students had the chance to experience motion capture technology. (Photos courtesy of Max R. Paquette, PhD.)

Geeking out in Memphis

NBD has been able to capitalize on the immense popularity among young people of video games and animation, which provides a major intersection with biomechanics, according to Max R. Paquette, PhD, who is an assistant professor in the School of Health Studies in the unit of Exercise, Sports and Movement Sciences as well as director of the Sports Performance and Health Consulting Center at the University of Memphis in Tennessee.

"NBD really is a big geeking-out event," Paquette said. "Video capture techniques are huge in biomechanics, but also are the basis for gaming and animation, so the younger generations are already attracted to that field and many will find work there."

Sports examples were universally exciting for students, participants said. NBD falls near the date of The Masters golf tournament and the beginning of baseball season, so Paquette placed emphasis on motion capture of golfers at last year's NBD and a 3D model that simulated baseball pitching mechanics this year. Students who visited the Memphis lab also saw and experienced how electromyography, motion capture, and force platforms can depict muscle activity and jumping biomechanics.

One of the most popular events was the demonstration of a new kind of ankle foot orthosis designed and constructed by Denis DiAngelo, PhD, ME, professor of orthopedic surgery and biomedical engineering, and Chloe Chung, a doctoral engineering student who works with Paquette and Douglas Powell, PhD, assistant professor of health studies, from the University of Tennessee Health Science Center in Memphis.

Chung explained to the children how the brace has very small

Continued on page 32

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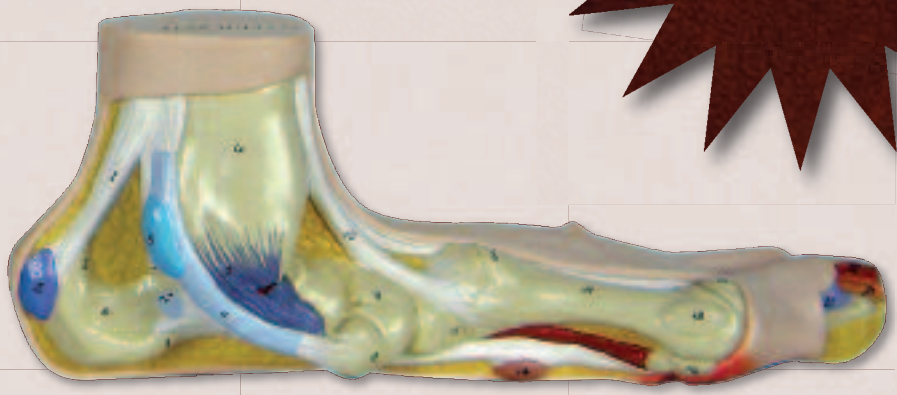

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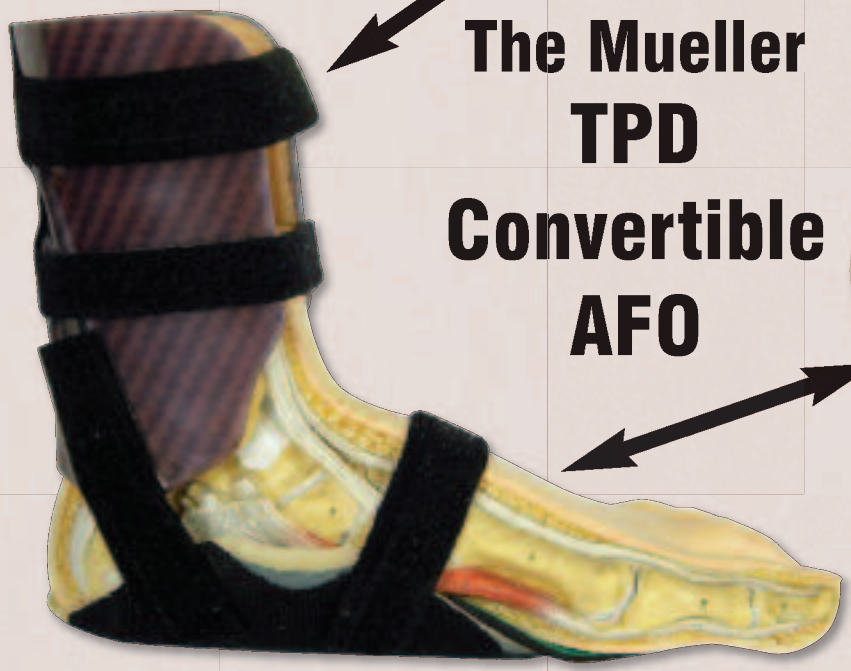

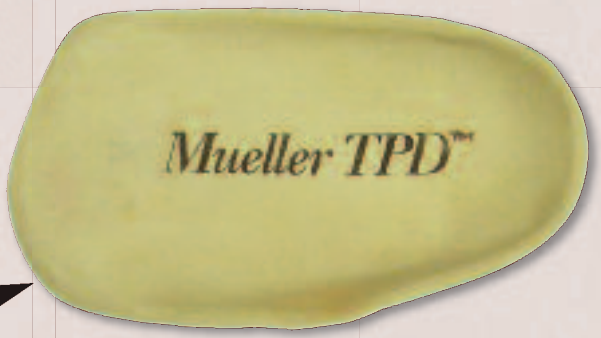

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At the University of Florida in Gainesville, activities such as acrobatic yoga helped teach second- and third-graders about counter-balancing concepts. (Photos courtesy of Chris J. Hass, PhD.)

pressure cylinders on each side that allow the ankle to move not just in flexion and extension, but also in inversion and eversion; the designers hypothesize this movement will facilitate the healing of ankle injuries.

"The students were fascinated by how changes in this brace could change movement patterns," Paquette said.

Connecting in Gainesville

Chris J. Hass, PhD, president of the ASB, said the NBD is intended to open the field of biomechanics to more students in general, with an emphasis on increasing underrepresented populations.

"Biomechanics is a career niche where almost everything we do focuses on an application that can enhance human performance. My particular emphasis is on increasing the number of females in the field," Hass said. "Many young girls turn away from science education in their teen years. There's a disconnect there, and we think biomechanics can provide a bridge to STEM [science, technology, engineering, math] education in college."

He pointed to the role biomechanics has played in understanding the mechanisms that can contribute to a higher incidence of anterior cruciate ligament injury in female athletes than in their male counterparts,[1,2] for example.

"Biomechanics also played a huge part in the creation of prehabilitation as a mindset, with the goal of using research findings related to injury mechanisms to develop conditioning programs to reduce the incidence of injury," Hass said. "Without the ability of biomechanics to measure and quantify the actions that lead to injury, we wouldn't have the effective preventive programs[3,4] that are available now."

NBD events at the University of Florida in Gainesville, where he is professor in the Department of Applied Physiology and Kinesiology, involved second- and third-grade students. Hass said he was shocked these youngsters had the capacity to follow presentations about servomotors and prosthetic devices.

"It was pretty impressive. And we included the kids in things like acrobatic yoga, which helped explain counter-balancing and maintaining the center of mass within the base of support," he said.

Motion capture in Las Vegas

Across the country, Janet S. Dufek, PhD, FACSM, reported that high school students submitted essays to their teachers to compete for the chance to go to the NBD event at the University of Nevada-Las Vegas (UNLV),

"Upon arriving in the laboratory, we first gathered students' data, giving them a number rather than a name, just to introduce them to human-subject procedures," said Dufek, who is associate dean of the School of Allied Health Sciences and professor in the Department of Kinesiology and Nutrition Sciences, where she focuses on the biomechanics of lower extremity function and gait. "We introduced them to motion-capture technology to evaluate maximum sprinting, force platforms for jumping evaluation, and quadriceps-hamstring relationships using isokinetic measures. These data were used to project the relationship between muscle strength and performance, which the students later saw projected correlationally and discussed."

At Elon University in North Carolina, biomechanists discussed gait analysis with 53 high school students. (Photo courtesy of Srikant Vallabhajosula, PhD.)

Continued on page 34

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The students were allowed to try spring boots on a force platform, run in a positive pressure treadmill, and walk and run on an instrumented treadmill where they could observe the relationships between their speed and the generated force vector.

On the radar in Delaware

About 175 high schoolers and 10 high school teachers rotated through 10 NBD demonstrations at the University of Delaware in Newark. Elisa S. Arch, PhD, research assistant professor in the Department of Kinesiology and Applied Physiology, said many students gained a new understanding of the potential of biomechanics for a career.

"Because of our NBD activities, several students want to pursue biomechanics applications for their senior capstone project. And one school decided to take their entire school on a day-long STEM field trip later in the year based on the excitement generated from their attendance at NBD," Arch said.

Yvonne Gabriel, who teaches at the Science and Mathematics Academy at Aberdeen High School in Maryland, took her advanced high school classes to Delaware's NBD events this year and last year.

"Biomechanics wasn't on most of my students' radar before National Biomechanics Day," Gabriel said. "Afterwards, a bunch of them asked to change their next-year elective to my course, where we teach research by looking at the human body."

Gabriel said her emphasis is on macrobiology.

"We look at gait, posture, and other things we see at NBD," she said. "Many students are athletic and are interested in movement, so that's how we 'trick' them into learning the research process."

Putting up numbers in New Zealand

The most successful NBD event outside the US was in New Zealand. More than 1000 high school students in metropolitan areas attended in person, and up to 150 others were connected by live streaming over the internet to their rural schools, according to Sarah Shultz, PhD, ATC.

"Strong government backing, from both a city council and a national ministry, as well as support from industry sponsors, helped provide demonstrations, equipment, and transportation of students to campus," said Shultz, a senior lecturer in the School of Sport and Exercise at Massey University in Wellington. "Check out @NZNBD on Twitter, Instagram, and Facebook to see the demonstrations. We had a lot of laughing and kids saying, 'Oh, cool!'"

Jumping and landing demonstrations were both low-tech (the aforementioned bubble wrap popping challenge) and high tech (instrumented mats). Shultz said a highlight was the appearance of a men's professional basketball player, who showed the students ways of landing to minimize the chance of knee or ankle injury.

Image courtesy of Sarah Shultz, PhD, ATC.

Hearts and minds in Chicago

Antonia Zaferiou, PhD, has experienced NBD at two different institutions. Last year she participated while visiting the sizeable event at the University of Southern California (USC) in Los Angeles. This year, she inaugurated the event with three sessions at Rush University Medical Center in Chicago, where she is director of Motion Analysis in the Department of Orthopedic Surgery.

At Rush, second- and third-graders switched between concurrent sessions. One brought biomechanics to life with interactive motion analysis and the engineering of a prosthetic hand prototype. The students were introduced to ground reaction forces by walking over force sensors in the floor using different strategies (eg, walk normally, then walk angrily). Then, they learned about prosthetics and the engineering design process, and built artificial hands from everyday materials. The other session was a dissection of a pig heart, led by Chris Ferrigno, PT, PhD. A postdoctoral fellow in the department, Ferrigno is part of the Science Alliance of Oak Park Education Foundation in Illinois, which financially supported Rush's National Biomechanics Day.

"I want to be the kind of doctor who always does this!" proclaimed a second grader while probing with scissors through the heart muscle.

Zaferiou entered biomechanics through her interest in physics and dance. She said dancers and other athletes naturally are students of movement and, if oriented toward science, can find a career in biomechanics or a related field.

"We have first-hand experience of what something like angular momentum feels like as we move and turn in dance," she said. "Biomechanics is a great way to enhance the experience of movement, giving us a way to understand movement patterns."

At Elon, NBD activities also included demonstrations related to postural control. (Photo courtesy of the Elon University Department of Exercise Science.)

Hands-on learning in Los Angeles

At USC, this year's NBD event not only reached some 200 high school students at campus laboratories, but also utilized Skype to connect with a high school class in Florida.

"Looking at form and function creates wonderful opportunities for students who like or need to move and understand how their body works and how they can use science and engineering to figure out the how-why of things working the way they do, such as in the difference in the structure and function of hip and knee joints," said Jill McNitt-Gray, PhD, FASB, FISB, Gabilan Distinguished Professor in Science and Engineering.

The most successful demonstrations were hands-on, McNitt-Gray said. The young students learned how muscles, joints, and bones work together, then constructed rudimentary working models

Continued on page36

Continued from page 35

At Sanford Sports Science Institute, NBD activities also involved fun with force plates. (Photo courtesy of KELO news.)

of a leg with paper towels, cardboard inserts, yarn, and other materials.

"They see how adjusting the placement of the muscles and the relative size of the tibia and femur, for example, affects how the 'leg' and 'joints' move," McNitt-Gray said. "At the end, they had to coordinate themselves to actually kick a soccer ball with the model leg."

USC was one of several NBD sites that partnered with community groups to reach underserved students and promote STEM education and biomechanics. The group developed learning modules involving different principles of biomechanics for the high school teachers to employ in their classes.

"It's important to equip teachers so they can guide the learning experience. What's cool is that biomechanics is the interface between physics, chemistry, and biology as we look at human movement," McNitt-Gray said.

Professional pathways in Akron

Brian L. Davis, PhD, professor and chair of the Biomedical Engineering Department at the University of Akron in Ohio, was one of the biomechanists who volunteered to help plan the inaugural NBD event at his university. He was only one of many biomechanists interviewed by *LER* who gave "massive kudos" to DeVita for coming up with the idea of a dedicated day for biomechanics.

"Ninety-five percent of the inspiration and vision was by Paul DeVita, and the others of us just followed his lead," Davis said via Skype while visiting his native South Africa.

More than 360 students and teachers from grades three to 11 enjoyed NBD at Akron, which included hands-on activities with diagnostic ultrasound, prosthetic legs, motion capture, and 3D simulation. Davis said the feedback received was testament to DeVita's vision. Teachers' comments included, "Our students had so much fun!" "Some girls who wanted to be doctors said now they'd like to get into engineering!" and "Some of our Nepali [immigrant] students never even travel outside of their neighborhood, so to be on a college campus was quite an experience for them."

Davis, among others, has a particular interest in attracting under-represented communities to biomechanics and related fields.

Photos courtesy of Texas A&M University (top) and Eastern Carolina University (bottom).

"Hispanics, African Americans, Appalachian communities, and others are a vast, untapped pool of talent, with the potential to help address our nation's pressing needs," he said.

Akron recently hosted "Biomedical Engineering: A Platform for STEM Outreach," a conference with the goal of creating a dialog that could lead to a national strategy for recruiting minorities. With National Science Foundation funding and support from Nike, some 60 junior high and high school teachers were among the 200-plus who attended.

"We've got to do some innovative things to attract young people today and prepare them even for jobs that don't exist now," Davis said. "I believe the ripple, multiplier effects these teachers will have on students and other teachers will help reach those individuals who need to be shown a path forward to a career."

The need is great in American inner cities, Davis said, but pointed to another frontier for consideration.

"Fully 200 million young people in Africa are ready to enter the work force and need these opportunities," he said. "All the areas that use biomechanics, from physics to biomedical engineering, to kinesiology, orthopedics, robotics, surgical instrumentation, and data analytics, can provide pathways to a viable future for them."

'Exploration for its own sake'

ASB President Hass noted three important results from this year's NBD.

"Number one was seeing the enjoyment of the children being exposed to science and its applications. Then, following all the cool things going on in labs across the globe through social media was really impressive," he said. "And finally, National Biomechanics Day was a reminder of how much fun and creativity come from learning about the scientific method. So, for a while, we [biomechanists] were able to enjoy exploration for its own sake instead of being caught up in how many research grants we're trying to bring in!"

Hank Black is a freelance writer in Birmingham, AL.

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Stress fractures: Lessons from military research

Lower extremity stress fractures are not limited to members of the armed forces, but have been studied extensively in military populations. That body of evidence has important implications for stress fracture prevention and management in runners, other athletes, and even nonathletes.

By Baris K. Gun, DO; Andrew C. McCoy, DPM; Kevin C. Wang, BS; and Brian R. Waterman, MD

In 1855, the Prussian military physician Breithaupt described a condition that he called "march foot" in soldiers who participated in long road marches or periods of sustained training.[1] This was later identified as the metatarsal stress fracture, which continues to plague us today, constituting an estimated 10% of all sports medicine injuries in athletic populations.[2] Although rarely occurring in other locations, such as ribs or the axial spine; 99% of stress fractures occur in the lower extremities.[2]

Stress fractures are frequently reported to affect distance runners and military recruits, but these injuries can affect any athletes, including those who participate in ballet, volleyball, rowing, basketball, and gymnastics. Although stress fractures in an athletic population occur more commonly in the athletic population compared with the .5% incidence rate reported in the general population, the exact incidence rate in athletes has not been well defined.[3]

However, stress fractures in military recruits—another population with high levels of physical demand—have been studied extensively. In the largest study to date, examining an at-risk US military population of 5,580,875 service members between 2009 and 2012, participants experienced 5.69 stress fractures of the lower extremity per 1000 person-years.[4] This risk is especially heightened with sudden increases in physical demand, such as military boot camp. In a 1999 study of 1296 randomly selected male Marine recruits, 4% were found to have incurred a stress fracture during basic training.[5]

The economic cost to the military is profound, with some soldiers undergoing prolonged treatment requiring a medical separation board, during which their status must come under review for possible separation (discharge) from active military service. Individuals who sustain stress fractures in basic combat training are removed from training and placed on rehab for an average of 62 days.[6] In fact, the single most powerful medical predictor of discharge during Marine basic training is a stress fracture, with a four-

Individualized risk stratification and adjusted training schedules are key to reducing the burden of lower extremity stress fractures in the military and other patient populations.

Continued from page 39


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fold higher rate of discharge in soldiers who suffer from a stress fracture, compared with those without this injury.[7] Given the analogous demands required of many military recruits during basic training, including repetitive, high-impact activity, this finding is likely broadly applicable to military trainees in the US Army and Marines, two branches of the military service with higher levels of physicality than other branches, though the stress fracture-related rate of discharge may not be as high in the US Air Force or Navy.

These injuries aren't restricted to elite athletes or military recruits. They also can be seen in anyone who increases high-impact training, such as running on hard surfaces or too rapidly, and have been reported following orthopedic procedures, including bunionectomy, metatarsophalangeal joint arthroplasty, and extensive rearfoot-ankle fusion.[8] Early identification and surgical intervention is key for "high-risk" fracture sites, which include the medial malleolus, talus, navicular bone, base of fifth metatarsal, and hallux sesamoids. These high-risk fractures are less likely to heal with rest and activity de-escalation alone.[9]

Stress fractures are caused by an overuse injury in otherwise healthy bones. Repetitive mechanical loading causes increased hydrostatic pressure.[10] Bone, being a dynamic tissue in accordance with Wolff's law, remodels in response to physiologic stress. However, osteoclastic resorption reaches its peak at three weeks, sooner than osteoblastic bone formation, which can take roughly three months to form normal lamellar layers.[11,12] This increase of bone resorption relative to bone formation is associated with partial or incomplete bone rupture, which can later be diagnosed by the "dreaded black line" on radiograph, magnetic resonance imaging (MRI), or bone scan.[13]

Nonmodifiable risk factors

Intrinsic risk factors for the development of stress fractures have been studied extensively. Studies focusing on military populations have identified female gender, initial entry to service, increasing chronological age, white race, enlisted rank, Army or Marines branch of service, increased bone turnover, anatomic malalignment, and decreased tissue or bone vascularity as risk factors.[4,13] Specific to the foot and ankle, intrinsic factors include a high longitudinal arch, leg-length discrepancy, and excessive forefoot varus.[9]

In a 2013 US Military Academy study, the cumulative four-year incidence of stress fracture was 5.7% for male cadets and 19.1% for female cadets.[14] Among all active duty service members, women are more than three times as likely to suffer a lower extremity stress fracture and more than seven times more likely to suffer a femoral neck stress fracture than men.[4]

There are many reasons why women may be at greater risk of lower extremity stress fracture than men. Anatomically, female bone geometry, with a smaller and narrower tibia than in men, and sex-specific differences in bone microarchitecture, with lower density and greater trabecular volume in women than in men, contribute to an increased risk for these injuries.[15] It does appear, however, that taller and heavier men in military service have a higher risk of stress fracture than taller and heavier women, which may be attributed to the greater bending strain experienced in long bones of men relative to women of comparable height and weight percentiles.[16,17] Military studies also have shown female service members have lower average physical fitness than their male counterparts, which is also associated with increased injury rates.[18,19]

Extremes of chronological age are also associated with an increased risk of stress fractures. Teenaged service members are more than three times as likely to have a lower extremity stress fracture compared with those aged 20 to 24 years, and those older than 40 years are nearly six and a half times as likely.[4]

This bimodal distribution has multiple likely explanations. Young recruits may be more likely to suffer from stress fractures given their recent introduction to the intense, high-impact demands of boot camp that can be in stark contrast to a less-active, premilitary lifestyle. As service members age, the risk of fractures may decrease as they become more accustomed to the physical rigors of military life. Additionally, bone mass peaks in young adulthood (around age 25 years for men and a slightly younger age in women).[20] After this peak, a slowly increasing rate of bone loss, primarily trabecular, begins, which may explain the increased rate of stress fractures in older service members.[16]

White individuals in the military are one and half times more likely to have a stress fracture than their African American counterparts.[4,21] This may be due to several factors, including bone mineral density and inherent bone geometry, which contribute to greater mechanical strength in African Americans.[16,22-24]

The physical demands placed on junior enlisted military members, compared with more senior-ranking and officer service members, as well as the physicality of the Army and Marines branches of service, relative to comparable populations in the Navy and Air Force, may account for increases in stress fracture incidence.[4]

Continued on page 42

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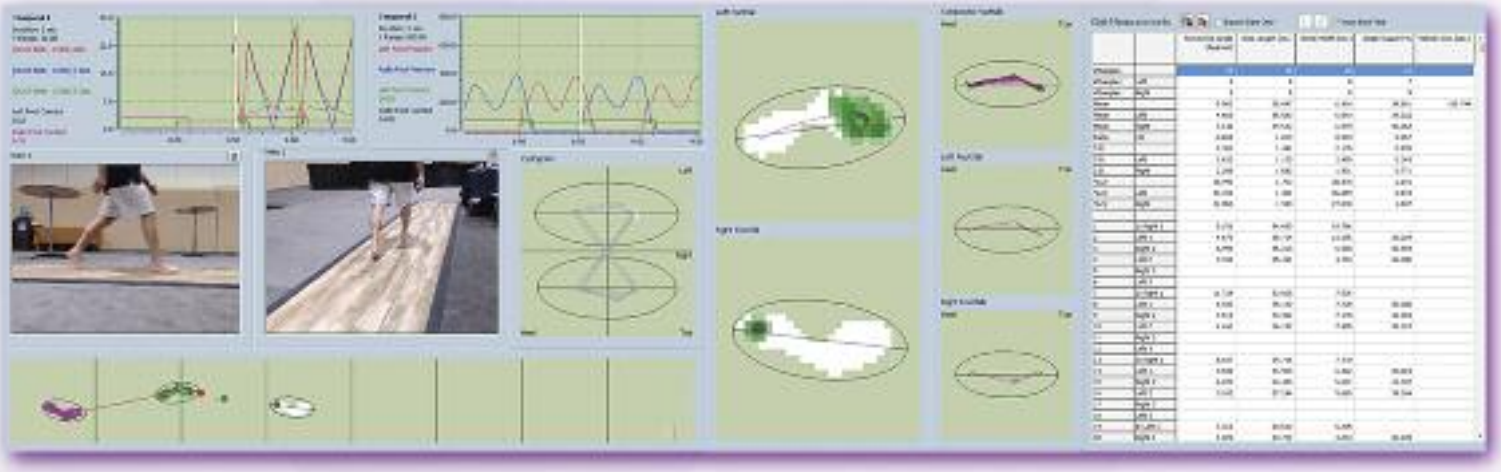

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Continued from page 40


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Modifiable risk factors

To curtail the burden of stress fractures, a large portion of the medical and public health community has focused on modifiable risk factors. A plethora of modifiable risk factors, including general physical fitness, muscle endurance, bone density, training regimen, dietary profile, footwear, training surface, and steroid, tobacco, or alcohol abuse, have been established for all individuals experiencing high-impact activity, and these findings have been applied to the military population.[10,13,25]

Although many modifiable risk factors are multifactorial, a sedentary period followed by a sudden increase in activity appears to be one of the strongest contributors to the development of stress fractures. Nowadays, many recruits have a sedentary lifestyle or a relatively low level of physical fitness prior to initiating basic training, which can put them at risk for stress fracture. The majority of stress fractures in the 2013 Cosman et al study[14] of West Point cadets occurred in the first three months of the four-year study. Cadets who exercised less than seven hours per week in the year prior to matriculation were at double the risk of developing a stress fracture compared with those who worked out more than an hour a day.[14] One reason for this is that lower levels of fitness result in greater relative effort, using a greater proportion of maximum strength, which results in higher perceived effort, more rapid fatigue, and consequently poorer form and mechanics—all of which can contribute to injury.[16]

People with extremely high or low body mass index (BMI) are at heightened risk for stress fractures, although interestingly, in the military, underweight recruits appear to have the greatest risk for tibia and fibula stress fractures, whereas in the civilian population increased risk is associated with obesity.[26-28] Many orthopedic injuries are associated with a similar bimodal BMI injury distribution, as increased weight causes increased loads through a patient's musculoskeletal system, and lower than normal BMI is associated with poor bone density.[29] It has been demonstrated that overweight football players are 19 times more likely to suffer a noncontact ankle sprain than those with a normal BMI due to the increased instantaneous joint loads and angular momentum;[30] these can also contribute to overuse injuries over time. Repetitive motion injuries, including stress fractures, are often associated with activities like ruck marching, where the same standard-weight sack represents a larger percentage increase of total cyclical load in a small or underweight person than in a heavier person. Additionally, entrance to military service requirements screen out individuals with very high BMIs.[31]

Deficiencies in calcium and vitamin D levels have been investigated and increase risk for the development of stress fractures.[32] Supplementation is an effective treatment for these risk factors. Lappe et al demonstrated that an addition of 2000 mg of calcium and 800 IU of vitamin D supplementation per day in female military recruits led to a 20% reduction in stress fracture incidence.[29]

Long-term alcohol use and high-volume consumption have been associated with low bone mass in general, and a higher incidence of stress fractures in women.[33,34] Smoking (currently or in the past) has been associated with a negative impact on bone health and an increased incidence of stress fractures; higher numbers of packs per day and more years of smoking can further increase the relative risk of stress fractures.[33-35]

Prevention

Adjusted training schedules and individualized risk stratification can successfully reduce stress fracture risk.[22,36] Intensity of training should gradually be increased over a number of weeks, with high-strain sport-specific activities beginning approximately six weeks after graduated training.[11] Early trials of physical readiness training programs and individualized injury-prevention programs have shown promise, and these programs may eventually be employed for higher-risk service members.[37,38] Although the Air Force issues soldiers running shoes for physical training and is the service branch with the lowest incidence of stress fractures, there is limited evidence that shock-absorbing insoles prevent stress fractures.[13] Activity-specific athletic shoes should be in good condition and replaced every 200 to 300 miles.[11]

The relationship between stress fractures and BMI in the military population may come from a number of causative factors, and these should all be considered in an effort to reduce the BMI-specific risk for stress fractures. Lower-BMI service members may demonstrate decreased lean muscle mass or nutritional deficiencies, two problems that can lead to decreased bone mass or increased risk for bone injury.[28] Higher-BMI individuals subject their skeletons to higher biomechanical loading during high-impact exercise and should be encouraged to lose excess weight to reduce the risk of stress fractures. Thus, BMI may dictate the physical fitness goals of military service members, with those with lower BMI focusing on increasing strength and lean body mass with resistance

> A sedentary period followed by a sudden increase in activity appears to be one of the strongest risk factors that contribute to the development of stress fractures.

training and adequate nutrition, and those with high BMI focusing on reducing caloric intake and body fat percentage.

Calcium and vitamin D supplementation have been widely promoted for prevention of fragility fractures, especially when a nutritional deficiency exists.[29] Further studies have shown that serum vitamin D levels greater than 40 ng/mL are associated with a lower risk of stress fractures and are recommended for stress fracture prophylaxis.[39,40] Oral contraceptive pills, taken by women with hypoestrogenic amenorrhea, have not proven in longitudinal prospective studies to increase bone mineral density or to decrease stress fracture risk.[41]

A thorough assessment of lifestyle factors should be included in any stress fracture prevention physical exam. Examinations of patients exercise routine and frequency, as well as alcohol and tobacco consumption, should be an integrated part of stress fracture prevention.

Conclusion

Lower extremity stress fractures are classically associated with the military and elite athletes; however, they can affect anyone, especially those who experience a rapid increase in repetitive loading exercises. Early diagnosis, through clinical suspicion and advanced imaging, are critical to reducing the morbidity associated with stress fractures.

Individual risk factors are broken down into intrinsic and modifiable. Established intrinsic risk factors include female gender, increasing chronological age, white race, positions in the military with increased physical demands, and anatomical and pathologic disease processes. Modifiable risk factors include the aforementioned increases in training regimen, general physical fitness, dietary profile, and steroid, tobacco, or alcohol abuse. Adjusted training schedules and individualized risk stratification are key to reducing the burden of these injuries.

Baris K. Gun, DO, is an army physician stationed at Ft. Hood, TX, with a special interest in orthopedic surgery and sports medicine, especially as it relates to an active military population. Andrew C. McCoy, DPM, is a podiatric medicine and surgery resident at Jackson Memorial Hospital in Miami, FL. Kevin C. Wang, BS, is a fourth-year medical student at Northwestern University's Feinberg School of Medicine in Chicago. Brian R. Waterman, MD, is an orthopedic surgeon specializing in sports medicine and shoulder and elbow care at Wake Forest University in Winston-Salem, NC.

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Somatosensory deficits following ACL surgery

Research suggests light touch sensation in the foot and ankle may be negatively affected several years after anterior cruciate ligament (ACL) reconstruction—a finding consistent with studies that have reported decreased somatosensation in patients with other lower extremity conditions.

By Matthew Hoch, PhD, LAT; Steven Morrison, PhD; and Johanna Hoch, PhD, LAT

Injuries to the anterior cruciate ligament (ACL) are common in physically active populations. Although surgical reconstruction for this injury is frequently sought, patients may experience subsequent reinjury[1] and long-term consequences such as diminished self-reported function[2] and post-traumatic osteoarthritis (OA).[3,4] In many cases, these negative consequences may be associated with biomechanical alterations during dynamic activity despite extensive rehabilitation.[5]

Neuromotor deficits associated with quadriceps activation,[6] postural control,[7] and joint position and movement sense[8] have been identified in patients who have undergone ACL reconstruction (ACLR). These deficits may provide insight into sources of movement dysfunction in this population. The further examination of the impact of ACL injury on the somatosensory system may provide additional insights into the underlying causes of these impairments.

Many of the neuromotor deficits that occur after ACLR are thought to originate as a consequence of alterations in the function of the mechanoreceptors within the ligament itself.[9] These mechanoreceptors are important for movement, as they provide information to the central nervous system (CNS) regarding joint movement and position.[9] These mechanoreceptors also influence muscle spindle activity in the muscles that surround the knee, which can affect overall muscular stiffness.[9] The overall result of ACL injury is therefore widespread, negatively impacting the ligamentous and musculotendinous components of the somatosensory system, which can alter neural feedback to the CNS—a consequence that has been proposed to contribute to CNS reorganization and alteration of the motor output.[10] These alterations in ascending neural feedback, coupled with mechanical instability and abnormal joint movement, provide further justification for assessing the impact of ACL injury on somatosensory function.

While the ligamentous and musculotendinous components of the somatosensory system have been extensively investigated

Stimulating the somatosensory system during rehabilitation after anterior cruciate ligament reconstruction may be necessary for complete neuromotor restoration.

Continued from page 45

following ACL injury, less attention has been directed toward the third aspect of this system, the cutaneous mechanoreceptors. These mechanoreceptors are found in the skin and include Merkel, Ruffini, Meissner, and Pacinian corpuscles. These receptors respond to a range of mechanical stimuli in the form of pressure and vibration.[11] The density of cutaneous mechanoreceptors varies throughout the body, but higher concentrations are found in the glabrous skin on the hands and feet.[12,13]

It is possible that cutaneous somatosensation may be disrupted in individuals who have undergone ACLR because of damage to cutaneous nerves during surgical procedures.[14] However, diminished vibration perception and tactile acuity has been identified in lower extremity conditions unrelated to surgery, such as chronic ankle instability,[15-17] patellofemoral pain,[18] Achilles tendinopathy,[19] femoroacetabular impingement,[20] and hip and knee OA.[21,22]

Cutaneous mechanoreceptors are typically the only aspect of the somatosensory system in direct physical contact with the environment. Theoretically, diminished lower extremity cutaneous sensation, particularly in the feet, may increase the detection thresholds for recognizing perturbations and changes in terrain; this could ultimately increase the latency of motor responses evoked to compensate for any such perturbations. Any neural delays linked to ACL injury could lead to further neuromotor deficits, biomechanical alterations, and reinjury mechanisms.

The study of alterations in cutaneous sensitivity associated with orthopedic conditions is an emerging area of research. Further understanding of how ACL injury leads to sensory changes may help us cultivate novel approaches to movement dysfunction, rehabilitation, and the development of OA in this population.

Study findings

We conducted a study[23] to determine if differences in lower extremity cutaneous detection thresholds were present in post-ACLR patients compared with healthy controls. For this case-control study, 15 participants were included in each group. Individuals were included in the ACLR group if they were at least one year post-ACLR and cleared for physical activity, had self-reported participation in all activities considered meaningful to the patient, were at least moderately physically active, and aged between 18 and 35 years. The ACLR and healthy groups were matched for gender, limb, and age. The ACLR group had a median time from surgery of four years.

Light touch detection thresholds were assessed at four locations on the foot and ankle: the head of the first metatarsal and base of the fifth metatarsal, medial malleolus, and lateral malleolus. Participants were positioned prone on a plinth with noise-reducing headphones. Cutaneous sensation was assessed using a 20-piece Semmes-Weinstein monofilament (SWM) kit. These monofilaments were selected for this study because they provide a method of assessing light touch sensitivity commonly used in clinical practice. Monofilaments were applied perpendicular to the skin with enough force to bend the monofilament into a "C" shape. The participants were blinded to monofilament application and instructed to state "yes" when a monofilament was perceived. A stepping algorithm[24] was used to determine detection thresholds. Based on the patient's responses, the monofilament weight was decreased or increased until a detection threshold was identified. We recorded the lightest weight monofilament that could be detected in at least 50% of applications.

Participants in the ACLR group had higher detection thresholds at the head of the first metatarsal and medial malleolus than the healthy controls. However, no differences in detection thresholds were identified at the base of the fifth metatarsal or lateral malleolus. At the head of the first metatarsal, 80% of the ACLR participants had detection thresholds of 3.84 or greater, which would be classified[25] as "diminished protective sensation," while 87% of the healthy participants had detection thresholds of 3.61 or lower, which would be classified as "normal sensation." These findings suggest physically active individuals with a history of ACLR exhibit cutaneous sensation deficits at the foot and ankle.[23]

Cutaneous somatosensation and the knee

Until recently, investigations examining cutaneous sensation after ACLR have been primarily focused on sensory deficits related to surgery. For example, involvement of the saphenous nerve has been documented following ACLR using a hamstring or patellar tendon autograft.[14,26-31] In our study,[23] decreased sensation over the medial malleolus could have been related to surgical involvement. However, we also observed decreased sensation over the head of the first metatarsal, which is associated with tibial nerve distribution and is not commonly impaired following surgery. Therefore, we hypothesize the sensory deficits identified in our study are related to sensory reweighting rather than surgical intervention.

Additionally, Thorlund and colleagues[32] examined the vibrotactile detection threshold of the medial malleolus and medial femoral condyle in individuals who were at least 10 weeks post-ACL injury

Continued on page 48

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Continued from page 46

or at least 16 weeks post-ACLR, compared with controls. Interestingly, this study determined the ACL/ACLR group demonstrated greater sensitivity than controls at the medial mallelus; however, their was no difference at the medial femoral condyle. Although the results of this study contradict our findings, a primary difference between the two studies is the time since surgery. Patients in our study were at least one year post-ACLR, and the median time from surgery was four years; by comparison, patients averaged 14 months since surgery in the study by Thorlund et al.[32]

Prospectively monitoring somatosensory changes after ACL injury and subsequent reconstruction may provide insight into the natural course of sensory alterations that occur. The initial response to injury or surgery may be to heighten sensation as a protective mechanism, followed by an inhibition of sensation in the later stages of recovery.

The hypothesis that sensory inhibition may be experienced over time is supported by studies that have looked at cutaneous sensitivity in patients with knee OA without total knee replacement.[21] In patients with knee OA, vibratory detection thresholds were increased at the first metatarsal, medial malleolus, lateral malleolus, and medial and lateral femoral condyles, compared with healthy controls.[21] The authors concluded these sensory deficits may be associated with the neuromechanical pathophysiology of knee OA; however, whether sensory deficits preceded OA development has not been determined.[21]

Similar findings have also been identified in hip OA patients.[22] However, these patients also exhibited decreased sensation over the radial head. This suggests somatosensory deficits may be generalized throughout the body; however, this concept has not yet been explored in any other patient populations.

Cutaneous sensitivity has also been examined in patients with a history of meniscectomy and in patients with active patellofemoral pain. Vibratory detection thresholds in patients who were on average four years since meniscectomy did not differ from those of controls at the medial malleolus or the medial femoral condyle.[32] In contrast, patellofemoral pain patients did exhibit light touch sensory deficits around painful areas of the patella compared with controls.[18] However, the average duration of patellofemoral symptoms was six years, with a range from one to 21 years. These studies indicate additional research regarding sensory deficits in different patient populations is warranted, and specific consideration should be given to time since surgery, type of surgery, the presence of pain, and duration of symptoms.

Clinical implications

Few studies have examined how decreased cutaneous sensitivity can influence functional movement performance or biomechanics. However, ACLR patients with diminished vibratory detection thresholds have also scored poorly on functional testing.[33] Further, women with decreased sensation at the first metatarsal and medial malleolus exhibited diminished movement quality during stair descent and the forward lunge, as indicated by an increased medialization of the knee position relative to the foot position during these tasks.[33] These sets of findings clearly suggest there is a need for further understanding of the implications of decreased sensation over the foot and ankle in ACLR patients, specifically in identifying the impact these deficits may have with regard to biomechanics and reinjury mechanisms.

Currently, there is a lack of understanding as to the origin of cutaneous sensory deficits. As previously mentioned, damage to the saphenous nerve can be a consequence of surgical intervention after ACL injury. However, we believe these deficits are not completely linked to surgery. A recent neurophysiological model to explain the neuromuscular deficits after peripheral joint injury proposed a loss of ascending afferent information as one of the

main factors contributing to CNS reorganization and motor control deficits.[10] This theory is supported by a growing body of evidence suggesting changes in the CNS after joint injury, supported by neurophysiologic measures of somatosensory dysfunction, motor system excitability, and plasticity of neural networks.[34-36]

Identifying the origin of cutaneous sensory deficits may be useful when developing relevant rehabilitation strategies. For example, purposeful stimulation of the somatosensory system may increase muscle activation following ACL injury. Modalities including transcutaneous electrical nerve stimulation and cryotherapy have been associated with increased quadriceps motoneuron pool excitability when applied to artificially induced knee effusions and patients with acute and chronic knee conditions.[37-40] Similarly, interventions focused on mechanical deformation of the skin and muscle tissues—such as whole body vibration, local muscle vibration, and massage—have also enhanced components of motor output.[41-43] Collectively, these studies highlight that increased emphasis on purposively stimulating the somatosensory system during rehabilitation may be a necessary component for complete neuromotor restoration. Considerably more research is needed to identify the most effective treatment strategies and their ability to improve patient outcomes.

Lastly, we believe these findings may have implications for long-term health. In addition to patients who have undergone ACLR, those with knee OA also exhibit decreased cutaneous sensation in the foot and ankle.[44] At this point it is not clear if there is a direct association between somatosensory impairment after ACLR and OA development. It is possible these are coincidental findings, because both groups have a history of intraarticular knee pathology.

Also, diminished foot and ankle sensation is a risk factor for falls in aging populations.[45] While somatosensory function degrades with normal aging,[46] it is unknown if this process is accelerated or exacerbated in people who sustained an ACL injury as an adolescent or young adult.

Investigating the role of somatosensory deficits as a contributing factor to OA development and fall risk are important, because these conditions may have more profound health implications than the original condition triggering the somatosensory effects. Furthermore, interventions may need to be developed that target somatosensory function throughout the lifespan to mitigate these conditions.

Conclusion

Patients who have undergone ACLR have demonstrated deficits in light touch sensation at the first metatarsal and medial malleolus compared with healthy persons. These findings suggest the somatosensory system may be affected several years after reconstruction, which is in line with recent research that has identified decreased cutaneous sensation in other lower extremity conditions. Continued research is needed to understand the role of somatosensory deficits with regard to reinjury mechanisms, CNS reorganization, and health issues experienced later in life, such as OA and falls.

Matthew Hoch, PhD, LAT, is an assistant professor; Steven Morrison, PhD, is a professor; and Johanna Hoch, PhD, LAT, is an assistant professor in the School of Physical Therapy and Athletic Training at Old Dominion University in Norfolk, VA.

References are available at lermagazine.com.

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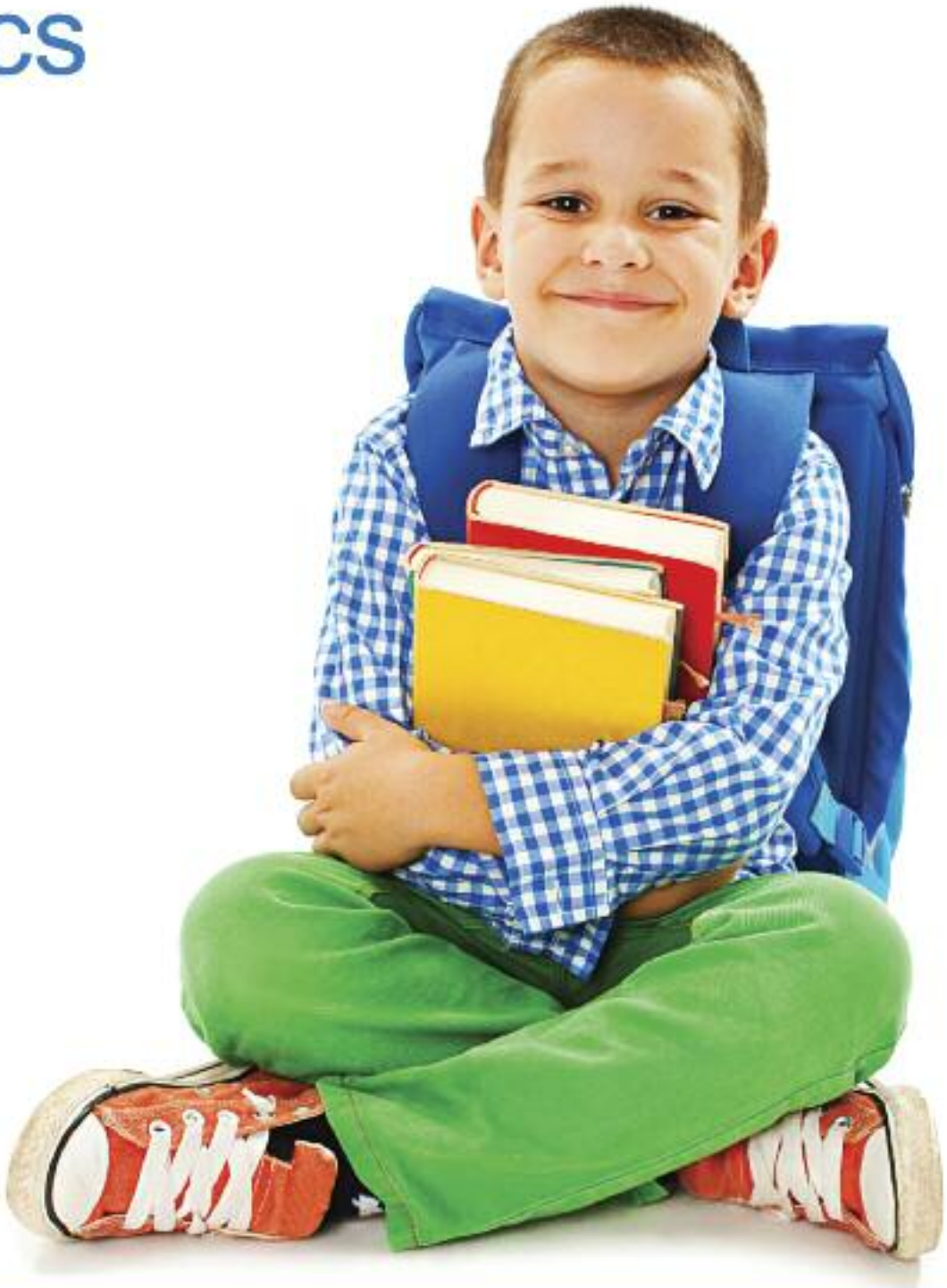

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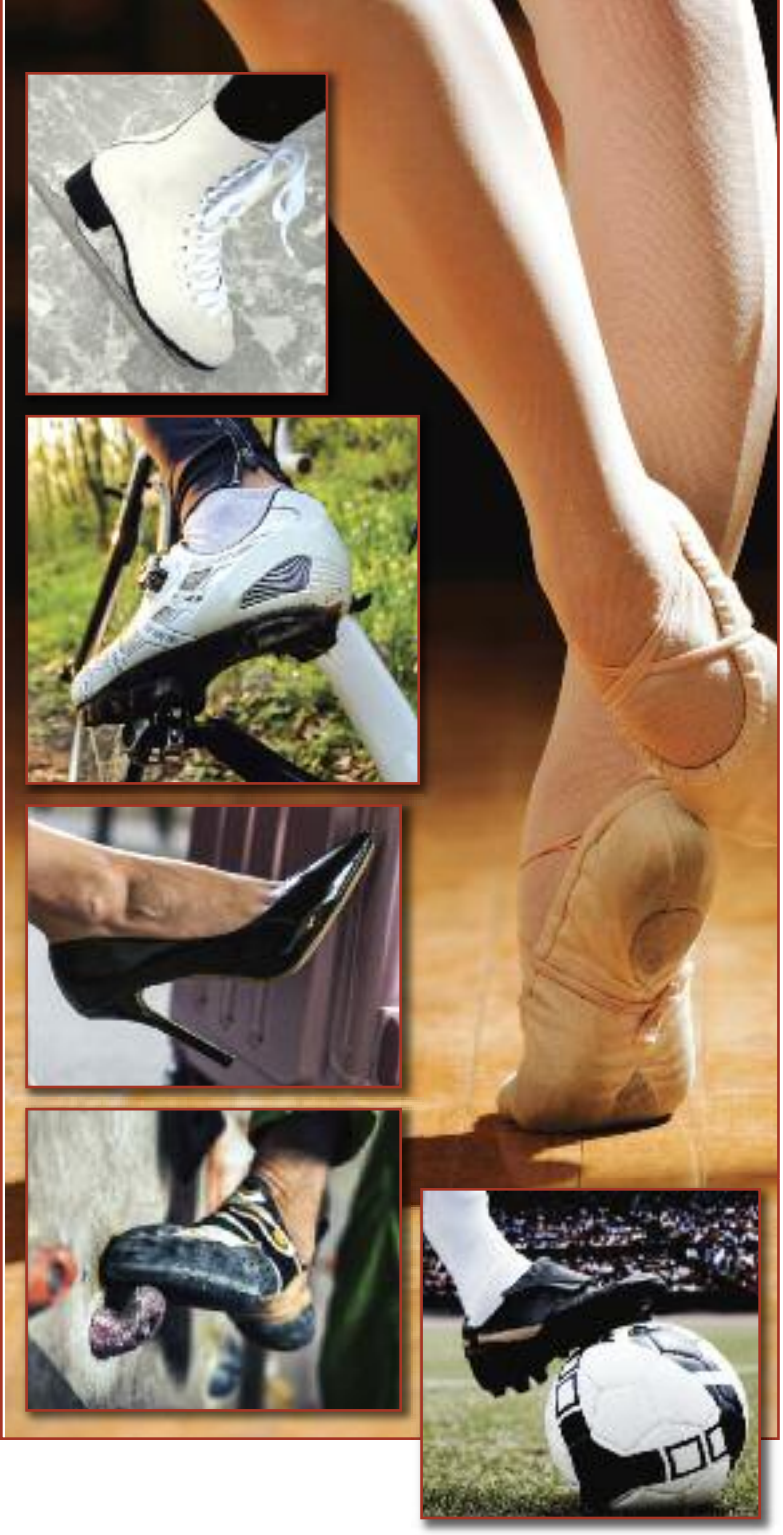

Unique orthotic strategies for low-volume footwear

The low-volume shoes worn by cyclists, figure skaters, and others can make orthotic management of these patients challenging. So, lower extremity practitioners have had to develop creative strategies for achieving the desired biomechanical effects while working within a limited space.

By Jill R. Dorson

Manolo Blahniks, soccer cleats, and an elegant new pair of figure skates might seem to have little in common. But—whether it's stylish high heels, cleats that allow an athlete to truly to feel the ball, or a boot balanced atop a narrow blade—form-fitting shoes do a job on the feet. And, with little room to negotiate, low-volume styles of footwear can make it a challenge to insert foot orthoses to relieve or prevent pain and injury.

But, experts say, regardless of how much room is available in a shoe, the goals of orthotic management are consistent.

"Whether for a women's dress shoe, skate, or a soccer cleat, the key is the biomechanical fit of the orthotic," said Robert Weil, DPM, a podiatrist based in the Chicago suburban area. "Orthotics are all about alignment."

Anecdotally, many practitioners prefer full-length orthoses for treating foot-related injuries or pain, but low-profile shoes—designed for anything from rock climbing to dance—often don't allow for a full-length solution. So, practitioners working with such cases have to get creative—using tape, felt, or super-thin rigid inserts—to find ways to support feet and align joints.

The challenges differ from one type of shoe to the next.

Cleated sports

On the face of it, cleats may seem an easy fit for foot orthoses. Roomier than many other athletic footwear (ie, cycling shoes, figure skates, or dance shoes), cleats present their own unique challenges, particularly when athletes have a preference for cleats that are too small. It is well known among clinicians that both soccer players and football kickers, for example, wear their cleats extra-tight to improve feel on the ball.

Multiple studies[1-3] have shown cleats are associated with increased pressure on the heel, lateral midfoot, and fifth metatarsal when athletes are running or turning. San Diego-based pedorthist and physical therapist Patricia Pande, PT, MCLSc, CPed, CSCS, has found tight cleats can also be associated with forefoot injuries. The

Regardless of how much room is available in a shoe, lower extremity clinicians say, the goals of orthotic management remain focused on alignment and biomechanics.

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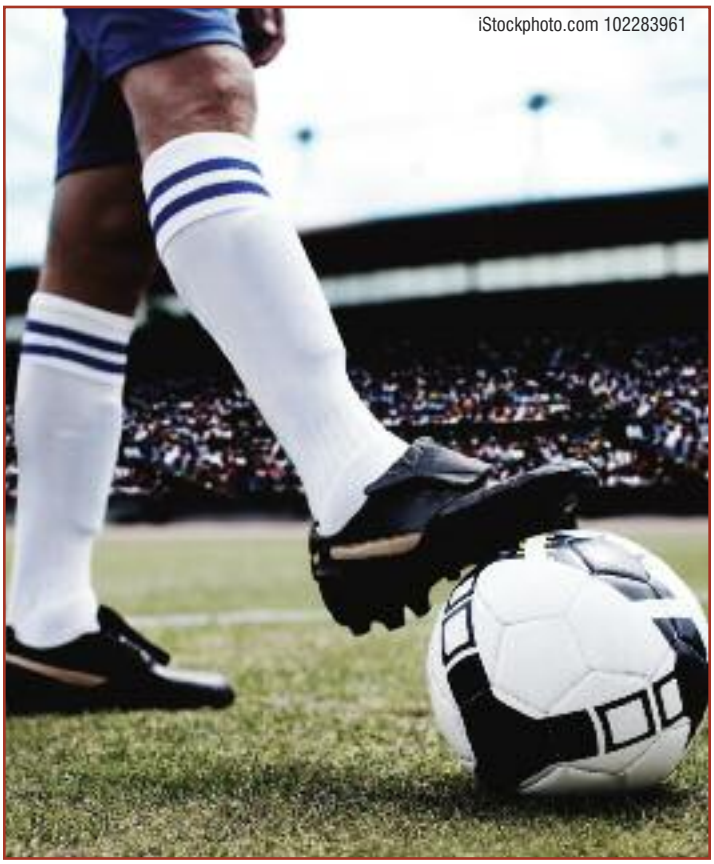

range of potential injuries associated with cleats is wide, and includes plantar issues, ankle sprains, and other soft tissue or bone injuries.

Pande, formerly of Kinetic Physical Therapy in North Carolina and a faculty member at the University of North Carolina Physical Therapy Faculty Clinic in Hillsborough, recently relocated to Southern California to focus on research, writing, and her consulting firm, FootCentric.

For cleated sports, Pande favors carbon fiber inserts, which she said can be semicustomized for each athlete. Pande said the carbon fiber allows practitioners to increase the rigidity of cleats to make the foot and shoe more stable, and fits well into low-profile shoes. The material can be heated and shaped, allowing for tweaks. However, while carbon fiber lasts longer than the felt or foam favored for dance-shoe inserts, Pande said its life span is about a year or two—which is shorter than the polypropylene used for other specialty insoles.

Since soccer shoes are, overall, bigger than many other athletic shoes, practitioners are able to fit a full insert into the shoes.

"When I do injury profiling, I try very, very hard to put in a full-length insert," Pande said. "Think about the excursion of the orthotic in the shoe. The shearing plays such a role in plantar fasciitis[4] and can cause skin issues."

As with other athletic shoes, the goal is to alleviate pain, redistribute pressure, and reduce the risk of injury. However, Pande is quick to point out that if the cleat is the "culprit," she recommends orthoses for the cleat only, but if there is a more pervasive issue, the athlete should have inserts made for each pair of shoes he or she wears.

Cycling

Few studies exist to test the use of orthotic devices in cycling shoes, which are typically made of rigid materials and are often attached directly to the pedal of a bike with toe clips. These shoes are not made for walking.

A March 2012 investigation in the German publication *Sportsverletz Sportschaden*[5] found that, compared with the standard insoles that come with cycling shoes, carbon fiber insoles for cycling shoes were associated with lower plantar pressures in all foot regions except the toes. In an Australian study of 12 cyclists published in January 2013 by the *Journal of Science and Medicine in Sport (JSMS)*,[6] contoured prefabricated orthoses were associated with greater foot contact area and greater perceived midfoot support than flat inserts of similar hardness. In a November 2011 *JSMS* study,[7] a different group of Australian researchers found no overall kinematic effects of custom foot orthoses in a group of 12 cyclists, but did find subject-specific effects.

Such studies tend to have small numbers of participants and other methodological limitations, making it difficult to identify the clinical implications. A May 2014 systematic review in the *Journal of Foot and Ankle Research*[8] concluded there is limited evidence supporting the use of insoles in cycling. In the August 2016 issue of the *International Journal of Sports Physical Therapy*, a review of interventions at the foot-shoe-pedal interface in cyclists reached a similar conclusion.[9]

The goal in using an orthotic device in cycling shoes typically is to better distribute plantar pressure while the cyclist's shoes are clipped to the pedals. Results of the German study showed a decrease in pressure using custom carbon fiber insoles.

The most common injuries in cycling often relate to overuse, according to the American Academy of Podiatric Sports Medicine.[10] Knee pain, shin splints, Achilles tendonitis, sesamoiditis, and numbness can often be traced back to the fit of the cycling shoe. A custom insert may help to solve these problems.

Custom orthoses for cyclists may be stiff (eg, carbon fiber or polypropylene) or more forgiving (eg, ethylene vinyl acetate [EVA]) depending on the nature of the injury or pain being treated. The only consistency in cycling inserts is size. Similar to dance shoes,

Continued on page 54

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Continued from page 52

the inserts are small and the focus is on the ball of the foot due to the limited amount of space inside the shoe.

An April 2014 *LER* article[11] explored in more detail the contradictions that arise when prescribing orthotic devices for cyclists and the lack of meaningful research on which to base this aspect of clinical practice. Experts interviewed in that article suggested that high-performance road cyclists may benefit from rigid inserts, while recreational cyclists may get relief from more flexible options.

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Dance shoes

Of all the challenges involved in getting foot orthoses into specialty shoes, dance shoes may present the toughest. Putting aside the fact that modern dancers go barefoot, leaving taping as the only real alternative, dance shoes often don't allow for a full-sized insole, according to Jeffery A. Russell, PhD, AT, FIADMS, an assistant professor of athletic training and director of science and health in artistic performance (SHAPe) at Ohio University in Athens. He noted a modified, smaller insert is usually the solution.

Like many other athletes, dancers often experience pain in other areas—such as the ankle, knee, or Achilles tendon—that can be related to foot issues. Pain associated with hyperpronation, according to a 2013 *Journal of Dance Medicine & Science* study,[12] is a common issue in dancers that can be alleviated with foot orthoses. The study found orthosis use was associated with a decrease in pain, as well as in the static medial longitudinal arch angle.

According to Russell, dancers often present with pes planus or pes cavus, both easily managed conditions. High arches can be treated with a simple D-shaped support in the center of the shoe/foot. A donut-shaped orthosis can be used to alleviate pain from a heel spur or a teardrop-shaped pad can be inserted behind the metatarsal arch to absorb some of the shock to the metatarsal bones.

Unlike athletes wearing more rigid shoes, insoles for dance shoes are usually made of orthopedic felt (a thicker, more durable cousin of art felt), closed-cell rubber foam, leather, cork, or a variety of soft and firm plastics. In Russell's experience, he has found that some of these orthoses require regular replacement (every few weeks) versus the longevity of a more rigid insert.

Among the biggest challenges is the ability of the dancer to become comfortable with the insole, which may require alterations to movement, Russell said.

"We're not using a full orthotic, so we'll often craft them ourselves," he said. "If you've been a dancer for years and years, it's going change the sensation of the entire foot and that can throw them off quite a bit. … The biggest thing is them getting used to it."

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Rock climbing

Like athletes who wear cleats, rock climbers tend toward wearing specialty shoes that are smaller than their regular shoe size to get better feel. Perhaps not surprisingly, rock climbers are prone to neuromas, bunions, and other foot issues caused by shoe pressure and rubbing.

A March 2013 *Journal of the American Podiatric Medical Association (JAPMA)* article[13] reported 86% of rock climbers sustain sport-specific foot injuries, ranging from nail disease to Achilles tendinitis. Anecdotally, experts say, the most common chronic injury is toe pain.

Jenny Sanders, DPM, principal podiatric physician at the Financial District Foot & Ankle Center in San Francisco, specializes in hiking and running issues. Sanders said her goal is to stabilize the big toe, though she often sees tendinitis (anterior tibial, posterior tibial, and Achilles) as well as plantar fasciitis. Climbing only once a week is enough to create foot issues, she said.

Rock-climbing shoes are made for a snug fit to allow the climber to better feel the surface he or she is climbing. Soles are generally stiff and may be thin, and the shoe can be downturned, forcing the foot into a plantar flexed position that is more conducive to climbing. Sanders said fit is critical to the sport, but suggests her patients go for a wider, if not longer, shoe to alleviate some issues.

Although the authors of the *JAPMA* article listed foot orthoses among the potential options for preventing and treating foot issues in rock climbers, Sanders said she prefers to tape her patients.

"There's not a lot to talk about that because climbing shoes are incompatible with orthotics. They're even incompatible with socks," Sanders said. "Taping is great for climbing shoes and really the only option."

Continued on page 56

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Continued from page 54


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Skates

Weil has decades of experience with foot orthoses and has worked with some of America's top figure skaters. When it comes to putting orthoses into any kind of skates, Weil said, there really is no downside.

"Balance, edging, propulsion, and stability are all enhanced with proper orthotics," he said, noting joint malalignment can cause skaters to experience back pain, knee pain, or foot pain. "Alignment becomes a very, very big deal, especially when you are really starting to jump."

Weil says there is little that is unique to fitting orthoses in skates, even tight-fitting figure skates. The boot of a figure skate is rigid—it may have up to three layers of leather—to provide ankle support, and the result is that other parts of the foot don't conform to the pattern of the leather. Most often, Weil said, the skater experiences foot problems before the skate itself wears out.

The durable materials most often used in making orthoses for skaters—polypropylene and sometimes graphite—are the same materials often used in other sports and for nonathletes. Unlike his counterparts in other sports, Weil said he rarely uses topcovers with orthoses for skates.

"Polypropylene is great because you're never going to break it," Weil said. "And there are different kinds of graphite that can be made razor thin."

Weil's anecdotal experiences are backed up by an August 2016 *Journal of Sport Rehabilitation* study,[14] which reported notable improvement in postural stability after skaters used custom insoles for six weeks. The study found center of mass sway and ankle sway were reduced, leading to improved balance.


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Dress shoes

High-heeled shoes can put exceptional pressure on the ball of the foot, causing capsulitis, calluses, Morton's neuroma, or sesamoiditis, according to Larry Huppin, DPM, clinical professor of podiatric medicine and surgery at Western University of Health Sciences' College of Podiatric Medicine in Pomona, CA.

While the height and tightness of the shoe often contribute to pain or injury risk, experts say a shoe's elevation is not critical when developing an insert. Rather, as with other low-volume footwear, it is space.

To that end, Huppin, who practices in Seattle, favors a cobra-shaped insole, which helps relieve pain in the ball of the foot but nearly eliminates the heel cup of a conventional foot orthosis. The cobra design provides support for the ball of the foot and the arch, but the heel cup is replaced by a piece that looks like a curved tail.

"The goal is to make or get [patients] into a prefabricated orthotic to grab the arch and transfer pain off the ball of the foot," Huppin said. "You're very limited in what you can fit into a dress shoe … so if I can get a cobra device that attaches really well to the arch of the foot, then I think I am doing the best I can do."

Huppin noted that women may experience pain in the forefoot, as well as overall foot fatigue, when wearing heels.[15-17] Such issues can be prevented by fitting an orthoses before pain arises, but Huppin also said that insoles, possibly in concert with other treatments, often resolve the issue. He is quick to point out that inserts "can take pressure off, but won't get rid of inflammation."

Whether custom or prefabricated, Huppin said foot orthoses for dress shoes are often made of long-lasting polypropylene with an EVA filler and a light topcover of either vinyl or leather. Overall, the device is rigid, but the cobra style allows for some flexibility in the heel. Because the orthoses are not truly full-sized, Huppin said, they won't last as long as a polypropylene version made for roomier shoes, but should last several years. ler

Jill R. Dorson is a freelance writer based in San Diego, CA.

References are available at lermagazine.com.


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Samuel Hubbard Ivy Legend

Samuel Hubbard now offers the Ivy Legend men's shoe line. Available in hand-colored black leather, cordovan, or whiskey leather with an antique finish, the shoes feature a classic loafer design with hand stitching and pin-tucking details. The Ivy Legend shoes also feature a Vibram sole to help provide all-day support, a lightweight Kevlar shank for sturdy arch support, and a triple-density memory foam insole topped with silky smooth leather, which can be easily removed. The shoes are designed to be easy to resole, for years of comfort. Priced at $235, the Ivy Legend shoes are available in sizes 7-14.

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LoRox Aligned Travel Roller

OPTP has expanded its options for portable foam rollers with the new LoRox Aligned Travel Roller, produced in partnership with fascia and body alignment expert Lauren Roxburgh, CSI. Made of durable, moderate density EVA (ethylene vinyl acetate) foam, the compact roller (12" long by 4" diameter) is suitable for travel or taking to the gym or studio. The Travel Roller is designed to elongate muscles, tone the body, and provide regenerative massage to improve blood circulation throughout the fascia, skin, and joints. Raised, circular bumps assist with lymphatic drainage and help decrease inflammation.

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Pro-Tech Orb Extreme Mini

Now available from Pro-Tech Athletics is the Orb Extreme Mini myofascial release ball, in a smaller size (3" diameter) than the company's Orb Extreme deep tissue massage ball. The ball facilitates single-point myofascial release to promote flexibility and deep tissue massage to reduce muscle fatigue and tightness and enhance performance. Therapeutic targets for the Orb Extreme Mini include the iliotibial band, hamstrings, quadriceps, and calf muscles. The release ball is nontoxic, latex free, and composed of closed-cell EVA (ethylene vinyl acetate)/polyolefin foam. It contains no phthalates or heavy metals.

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The Adrenaline GTS 17 from Brooks Sports has been updated with a more streamlined look and softer feel underfoot. The Adrenaline shoe still features a secure, comfortable fit while providing support, and is equipped with a full-length segmented crash pad to accommodate any type of foot landing. The shoe also features a progressive diagonal roll bar to guide the body back into its natural motion path. An asymmetrical saddle with adjustable eyelets improves the fit by pulling from the heel. Priced at $120, the Adrenaline running shoe is available in a range of colors for both men and women.

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market mechanics

By Emily Delzell

OpWalk Carolinas donates care in Cuba

Three Charlotte, NC-based healthcare organizations on May 10 sent medical staff and resources to Cuba to perform critical hip and knee replacements.

The Operation Walk Carolinas team, which included surgeons, internists, physical therapists, nurses, and scrub techs from OrthoCarolina, Carolinas HealthCare System, and Novant Health Operation, did more than 51 hip and knee replacements (some bilateral) on 46 patients in three full days in the operating room.

There was a separate day of screening, and the OpWalk Carolinas team provided advanced orthopedic care education to Cuban physicians, few of whom are trained in joint replacement surgery, according to an OpWalk release.

Carolinas Healthcare made a $33,000 in-kind donation of medical supplies, and a few staff joined the team from Georgia-based CrossLink Orthopedics and Kalamazoo, MI-based Stryker, which also donated implants. Concord, NC-based Hendrick Motorsports donated chartered flight services.

Visit opwalkcarolinas.org for more information. ler

Podimetrics mat system predicts DFUs

A study epublished on May 2 in *Diabetes Care* found Somerville, MA-based Podimetrics foot mat and monitoring system, designed to assess plantar temperature asymmetries and predict diabetic foot ulcers (DFUs), detected most DFUs and was well-accepted by patients.

During the 34-week multicenter cohort study, 129 patients with diabetes and prior DFUs used Podimetrics' Remote Temperature Monitoring System at home. The system analyzed data and shared them wirelessly with investigators.

Of the participants, 37 (28.7%) developed 53 DFUs. At an asymmetry of 2.22° C the standard threshold used in previous studies, the system identified 97% of observed DFUs correctly, with an average lead time of 37 days and a false-positive rate of 57%.

Increasing the temperature threshold to 3.20°C decreased sensitivity to 70% but reduced the false-positive rate to 32%, with the same lead time of 37 days. About 86% of the cohort used the system at least three days a week on average. ler

AAOS releases guidelines for hip OA

The Rosemont, IL-based American Academy of Orthopaedic Surgeons (AAOS) in April released a new clinical practice guideline (CPG) on treatment of osteoarthritis (OA) of the hip.

"The strongest CPG recommendations supported the use of intraarticular corticosteroids, physical therapy, and non-narcotic pharmacologic management as conservative treatments for patients with hip osteoarthritis prior to total hip replacement surgery," said Gregory Polkowski, MD, chair of the hip OA CPG work group.

The CPG is available at orthoguidelines.org and through the AAOS mobile app. ler

BOC moves to expanded headquarters

The Board of Certification/Accreditation (BOC) reported in May that it will move from its current offices in Owings Mills, MD, to a larger space in the same city. The BOC will close during the June 1-6 transition.

The BOC's address after June 6 is 10461 Mill Run Circle, Suite 1250, Owings Mills, MD, 21117. ler

CMTA study is AAOS "Game Changer"

The Charcot-Marie-Tooth Association (CMTA) in April announced a study sponsored by the Glenolden, PA-based nonprofit found the three leading procedures for treating heel deformities don't correct the problem adequately.

Investigators at Cedars-Sinai Medical Center in Los Angeles used 18 identical 3D prints made from computed tomography scans of a single CMT patient's heel to create models, which they used to compare the three most common surgical correction methods.

The results found none of the techniques provided adequate correction of the deformity.

"This is one of the first times three-D prints have been used in orthopedic research, and we're thankful for the support of CMTA to use this new technology to help improve patient care," said Glenn B. Pfeffer, MD, lead study author and codirector of the Charcot-Marie-Tooth Center of Excellence at Cedars-Sinai.

The American Academy of Orthopaedic Surgeons chose the study as one of six presented at its "Game Changers" session (techniques most likely to change practice in the next three years) at its annual meeting in March in San Diego. ler

Allard USA appoints Williams CEO

Rockaway, NJ-based Allard USA announced in May the appointment of Dennis Williams, CO, BOCO, as CEO. He assumed responsibilities on May 1, succeeding James Button.

Williams was previously president and COO of Chattanooga, TN-based Fillauer Companies, executive vice president and partner of Biomedical Horizons in Jackson, MI, and director of sales and marketing for Camp International (now TruLife), also in Jackson. ler

Össur contest to send winner to Reykjavik

Foothill Ranch, CA-based Össur in April invited people of all ages with limb loss to celebrate their accomplishments with #MyWinningMoment, an online contest in which people share their stories on mywinningmoment.com.

Entering is free, and the winner gets a three-night trip for two to Össur's global headquarters in Reykjavik, Iceland.

Enter by June 30, and go to mywinningmoment.com for more details. ler

NATA wins ASAE excellence award

The Carrollton, TX-based National Athletic Trainers Association (NATA) announced in May its win of a Gold Circle Award in the website category at the American Society of Association Executive's (ASAE) 2017 Marketing, Membership & Communications Conference, held May 2-3, in Washington, DC.

The Gold Circle Awards recognize excellence, innovation, and achievement in marketing, membership, and communications by associations and nonprofits. The ASAE this year received more than 172 entries in 11 categories. ler

OPTP releases professional catalog

Minneapolis, MN-based Orthopedic Physical Therapy Products (OPTP) in April published the 37th edition of its semiannual professional catalog.

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