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In search of a mechanism for foot orthoses' effects

The seemingly endless quest to discover why foot orthoses relieve symptoms is veering away from skeletal alignment and toward somatosensory variables, though some researchers and practitioners still insist that kinematics play a role as well.

By Cary Groner

Many people who are prescribed foot orthoses conclude that they reduce pain, and that's good enough for them. Researchers and clinicians are rarely content to leave it at that: if the pain goes away, they want to know why. They'd like not just understanding, for that matter, but repeatability. And lately, the researchers have been saying to the clinicians: Good luck with that.

For many years, practitioners thought orthoses relieved pain largely by correcting structural alignment in the lower extremities, primarily abnormal pronation of the subtalar joint.[1] Some still think so. For the past decade, however, biomechanics researchers have begun to question these assumptions. Recently, the publication of *Biomechanics of Sport Shoes*, by Benno Nigg, DrScNat, professor of biomechanics and co-director of the Human Performance Laboratory at the University of Calgary in Alberta, generated press by suggesting that orthoses actually have little effect on gait kinematics.[2]

Some clinicians have embraced this thesis; others find it suspect. But most generally agree with Nigg's premise that we don't know exactly how orthoses work, that there's significant individual variation in response, and that practitioners are often unsure what to prescribe.

Across the bow

"My view is that the prescription of orthotics has been dominated too much by mechanical aspects," Nigg told *LER* via email. "The 'solution' may be that more functional (say muscular) aspects are included and that early intervention is checked by the clinicians."

The suggestion is founded on a history of fruitful speculation. Nigg fired his first shot across the bow of conventional thinking in 2001, when he published a paper in the *Clinical Journal of Sport Medicine* that proposed new paradigms for understanding the effect of impact forces and movement control in runners.[3]

In the article, Nigg noted that running injuries are often attributed to skeletal malalignment such as excessive foot varus or

Increasingly, researchers are focusing on studying the effects of foot orthoses on muscle activation, which may be related to alterations in sensory input.

valgus and tibial rotation. He proposed that the impact forces during heel strike be considered an input signal to which muscles respond with a "tuning strategy" that minimizes soft tissue vibration. This adaptation leads to a "minimal resistance movement path" for any given task. Interventions such as orthoses that support this path may decrease muscle activity, but orthoses that counteract the path will increase it. In any case, such interventions exert only small effects on skeletal kinematics.

Multiple factors

"I think there's a lot to that," said Thomas McPoil, PT, PhD, a professor in the School of Physical Therapy at Regis University in Denver. "We pick the way we walk and run because for our body and structure it's the most efficient. When I get pain, though, I may move out of that preferred pattern, modify my gait, and use muscles differently. It may be that the purpose of an orthotic is to put the person back into their preferred movement pattern and decrease that energy cost, rather than trying to alter skeletal alignment."

McPoil noted that studies typically show that orthoses exert an effect of only two or three degrees on alignment, and that even that may be overstated because most research is done with skin markers rather than bone pins.

"Can you really hang your hat on that and say the orthotic is controlling motion?" he asked. "Yet we know by the symptomatic response that it's helping—and that's the kick in the pants, because these things work."

Which presents the practitioner with a dilemma: What do you tell your patient?

"I think it's hard to look them in the face and say, 'We're giving you this to control your motion,'" McPoil said. "But you can say, 'We're doing something to control the amount of repetitive stress that's being applied to your tissue.' Now, that stress could be biomechanical, it could be neurosensory, it could even be shock; but there are multiple factors that influence the way you and your body perceive how that orthotic is helping you feel better."

The research

A number of theories have sought to explain and quantify orthoses' effects, in fact.

Regarding alignment, one study (noteworthy—and creepy—in that researchers actually used bone pins rather than skin markers on their courageous volunteers) reported that orthotic effects on eversion were small (between 1° and 4°) across subjects, and that significant effects were found only for total internal tibial rotation.[4] Another study found that subject-specific reactions to four different shoe inserts were inconsistent.[5]

Scientists have also investigated orthoses' effects on muscle firing. One paper reported that in adults with pes planus, orthoses improved selective activation of the tibialis posterior.[6] Another found that a semirigid orthosis did not alter muscle response times or activation patterns of the muscles that stabilize the knee.[7] In one case, researchers concluded that orthoses had significant effects on the biceps femoris and tibialis anterior groups, but not on the medial gastrocs, vastus medialis, or vastus lateralis.[8] In a study from Stanford, researchers reported that three orthoses tested affected lower extremity muscle activity differently, and that the effects were specific to the phase of running gait.[9] And researchers at the University of Virginia found that during slow, controlled exercises such as single-leg squats, vastus medialis and gluteus medius activity is enhanced with an orthosis regardless of posting or foot type.[10]

A number of studies[11-14] have reported enhanced activation of the peroneus longus, which could lead to better ankle stability, hence providing one explanation for how orthoses work. Researchers at La Trobe University in Australia found that orthoses appeared to increase peroneus longus electromyographic (EMG) amplitude.[12] The same scientists concluded that orthoses significantly altered tibialis posterior and peroneus longus EMG amplitude in subjects with flat feet, though only one of the orthoses tested moved the amplitude closer to that found in people with normal arches.[13] Finally, a 2009 literature review from the same team reported that orthosis use may be associated with greater EMG activation of invertor musculature in pronated feet and increased activation of tibialis anterior and peroneus longus.[14]

Another popular theory has to do with possible orthotic effects on sensory input and motor response. One study (the ubiquitous Nigg is a coauthor, as he is on many of these papers) found that decreasing plantar sensitivity using ice caused the center of pressure to move away from areas of lower sensitivity; the change in feedback significantly altered muscle patterns.[15] The Australian authors of a 2010 literature review speculated that foot orthoses may alter neuromotor recruitment patterns, helping to normalize intratendinous loads.[16]

To help sort all this out, in a 2010 study published in the *British Journal of Sports Medicine*, Australian scientists did a meta-analysis of literature pertaining to orthoses' potential mechanisms of action and reported findings in several categories.[1] Regarding kinematics, they concluded that posted, nonmolded orthoses reduced peak rearfoot eversion by an average of 2.12° and internal tibial rotation by 1.33°. In shock attenuation, molded orthoses significantly reduced loading rate and vertical impact force versus nonmolded orthoses and controls. The neuromotor category offered the least compelling data.

The authors concluded, tellingly, that there is great variability in how patients respond to orthoses. Sound familiar?

The black box

"I think there is evidence to support the notion that foot orthoses have an impact on the sensorimotor system independent of motion control," said Jay Hertel, PhD, ATC, director of the graduate program in athletic training and sports medicine at the University of Virginia.

He acknowledged, though, that scientists don't yet understand how changes in sensation affect muscle activation.

"It's really a black box within the central nervous system," he said. "We know we're changing the afferent information that goes into the CNS, and that we're getting an altered response from the muscles, but is that happening at the spinal level? In the motor cortex? There's a lot of research trying to open that box and see what's actually going on."

Define "small"

It's also important to note that what constitutes a small effect for a researcher may be a big effect to an individual patient. Nigg raises a crucial point that lies at the heart of the controversy but is hardly unique to the study of foot orthoses: Researchers need to be able to form conclusions based on group performance, whereas clinicians need only treat one patient at a time. The two goals, in fact, are mutually contradictory.

"[Researchers] must find 'functional groups' that react to interventions in a similar way, and find functional solutions for these groups," Nigg told *LER*. "From a clinical point of view, we must check the outcome of any intervention."

Bruce Williams, DPM, owner of Breakthrough Podiatry in Merrillville, IN, concurred.

"I like working with researchers and I want to continue to do so, but they're necessarily compiling statistics and taking averages," Williams said. "From the perspective of a clinician, those averages obliterate the things you're seeing in individual patients that you can actually deal with."

That conundrum hits home for Irene Davis, PT, PhD, director of the Spaulding National Running Center in the Department of Physical Medicine and Rehabilitation at Harvard Medical School.

"I agree that there are not compelling arguments that orthotics result in a consistent change in alignment," Davis said. "However, I disagree that they don't alter alignment. We're complex beings, and people may respond to an intervention in completely opposite ways."

In a study Davis and colleagues conducted several years ago,[17] some subjects given aggressively inverted foot orthotics responded with predictable alignment changes, but some actually everted even more than they had before, apparently in unconscious compensation for the orthosis.

"If you looked [at the subjects collectively], there was no difference in the rearfoot position across the three conditions tested," she said. "But if you looked *individually*, you would find people who clearly responded with alignment changes to the orthotics and some who did not."

Davis also pointed out that researchers may underestimate the import of their findings. For example, studies often report a change in alignment of "only" two or three degrees—but given that the total ankle excursion typically maxes out at about 10°, that may represent a significant effect.

"I think the small amounts researchers refer to may actually make an important difference in motion," Davis said.

Tom McPoil acknowledged that small changes could affect factors other than—or in addition to—alignment.

"We don't always know what's significant," he said. "People have very multifactorial and individual responses to orthotic devices. For some, a one or two degree change in motion may be enough, particularly if they're also responding to the neurosensory or shock-attenuation aspects of treatment."

Beyond the rearfoot

Some evidence suggests that researchers searching for significant kinematic effects of orthoses may simply be looking in the wrong places.

Investigators from the University of Salford in the U.K. are taking that search beyond the subtalar joint. In one study, for example, sagittal plane kinematics at the ankle, knee, and hip were evaluated in 20 subjects as they walked with and without an insole that restricted dorsiflexion of the first metatarsophalangeal joint.[18] Although the insoles were intended to experimentally replicate hallux rigidus or hallux limitus in healthy subjects, it's worth noting that the orthoses did affect kinematics at all three levels up the kinetic chain. In a more recent paper, the same authors noted that the rearfoot plays only a small role in overall foot kinematics and that those kinematics vary widely even within small groups of study subjects, suggesting a role for patient-specific clinical models of foot function.[19]

These types of orthotic effects on kinematics, however, can be practically difficult for researchers to quantify.

"I think orthotics have their biggest effect in the midfoot and the arch," said Davis. "More pronation happens in the midfoot than at the subtalar joint, but it's difficult to measure with our standard analysis techniques.[20] You've got to believe that if you put something rigid under the arch, the arch isn't going to deflect as much. I believe the talonavicular joint is one of the keys to the arch in the midfoot, and that orthotics have a big effect on that."

Studies of how wedged insoles affect the knee[21-24] also fly in the face of efforts to downplay the kinematic effects of orthotic devices, noted Michael Gross, PT, PhD, FAPTA, a professor of physical therapy at the University of North Carolina.

"I think orthotic effects are more mechanical than people want to admit," Gross said. "If somebody has a varus knee and medial compartment arthritis from the compressive stress on the medial side, a lateral wedge [in the shoe] will decrease the varus loading and possibly save them from having a total knee replacement. Conversely, with a valgus knee, a medial wedge decreases the compressive stress on the lateral side and the tensile stress on the medial side. There's plenty of evidence to support that."

Practice pearls

Clinical improvements associated with the type of alignment changes that may seem insignificant to researchers offer a different kind of evidence, Gross suggested.

"It often takes a very subtle influence of the orthotic to produce a small change in alignment, which then produces a dramatic change in symptoms," he said. "Those alignment changes are so subtle that if you try to identify them with motion analysis, they may not show up. But if the patient's pain diminishes significantly right away, that tells me I'm having a mechanical influence."

Gross acknowledged that some of this is science and some of it is art. "There aren't a lot of good randomized, controlled trials," he said. "What you do in the clinic is a little like research, though. You look at the literature, you examine the patient, you form a hypothesis, and then you test it with an experiment. That is, you fabricate an orthosis, give it to them, see the results, and modify it if necessary—and there's art in that."

Other practitioners also cite the need to consider traditional approaches.

"We can't just take forty or fifty years of clinical practice into alignment and motion-control orthotics and throw it out the window," said Jay Hertel. "I think there is definitely a place for motion-control orthotics and trying to realign the skeleton. We're developing clinical predictor rules—figuring out which patients are going to benefit from a specific approach. We need to look at multiple outcome measures, and the research in motion control and muscle activity, to identify the mechanisms that different treatments have."

The case for comfort

It might surprise some to discover that Benno Nigg is actually a fan of orthoses.

"If properly done, they can have fantastic positive effects," he said. "The results of our study with the military indicated that we had a total reduction of injuries by 53 percent.[25] The fact that the only selection criterion was 'comfort' suggests that people have an excellent sensory system to indicate whether or not an intervention

is good."

Nigg's research suggests that comfort has clinical relevance. One paper concluded that "evaluations of foot orthoses using comfort do not only reflect subjective perceptions but also differences in functional biomechanical variables."[26]

So could an alteration of sensorimotor function (which affects perceptions of comfort) be connected to muscle activation, and this in turn connected to effects on pain?

"This is certainly one possible and logical way to go," Nigg replied.

Including comfort in this complex equation brings the discussion full circle, of course. When a clinician prescribes orthoses, the ultimate judge of their success will be the patient, whose verdict will depend largely on the subjective experience of pain. This makes comfort, as a component of pain, potentially a determinant of orthotic effectiveness as well as an outcome measure.

"If I put in an orthotic, it may be providing a couple of degrees of motion control, but maybe it's also giving them sensory input," said Tom McPoil. "It's making them feel better by making them feel better, and their pain is decreased." ler

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References are available at www.lowerextremityreview.com