The Evolution of Foot Orthoses in Sports—Part 3

Here’s a review of the history and research on these devices.

BY KEVIN A. KIRBY, DPM

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Research on the Biomechanical Effects of Foot Orthoses

As mentioned previously in this article, over the last few decades there has been a surge in the quality and number of foot orthosis biomechanics research studies on both athletes and non-athletes. Much of the improvement in the quality of research studies on foot orthoses is likely due to many new technological advances that are now available.
Foot orthoses have now been conclusively shown to alter the motion patterns of the foot and lower extremities in numerous scientific research studies. Foot orthoses have now been conclusively shown to alter the foot and lower extremity kinematics and kinetics. Foot orthoses have now been conclusively shown to alter the motion patterns (i.e., kinematics) of the foot and lower extremities in numerous scientific research studies. Research has now shown a decrease in maximum rearfoot eversion angle, a decrease in maximum rearfoot eversion velocity, a decrease in maximum ankle dorsiflexion angle, a decrease in maximum internal tibial rotation, and a decrease in knee adduction.

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Figure 1: Research has shown that foot orthoses change the kinetics of gait by altering the internal forces acting on the segments of the foot and lower extremity. In the model illustrated above of the posterior aspect of a right foot with a medially deviated STJ axis, when the posterior tibial muscle contracts with increased force to cause increased tensile force on its tendon, an increased internal inversion moment will be measured (left). However, when an anti-pronation custom foot orthosis is designed for the foot to shift the orthosis reaction force more medial on the plantar heel and longitudinal arch, the resultant increase in external STJ supination moment from the orthosis (see Figure 4) will cause a decrease in posterior tibial muscle contractile force and a decrease in tendon tensile force which will also result in a decrease in measured internal inversion moment (right). It is by this proposed mechanism that foot orthoses may relieve symptoms and heal injuries in the athlete and non-athlete but, in doing so, may also cause little change in measured foot and lower extremity gait kinematics.
Foot Orthoses Alter Contractile Activity of Lower Extremity Muscles

Research has also shown that foot orthoses significantly affect the contractile activity of muscles during running and other activities. Foot orthotics were found to alter the EMG activity of the biceps femoris and anterior tibial muscles during running and to significantly change the EMG activity of the anterior tibial muscle during walking. Recent research has shown that changes in foot orthosis design may cause significant changes in EMG activity in many of the muscles of the lower extremity during running. A correlation between perceived foot comfort with different types of foot orthoses and the EMG activity of the lower extremity muscles has also been demonstrated.

Figure 2: Research has shown that foot orthoses may be designed to reduce the plantar pressures and forces acting on the foot. In the model above, a frontal plane cross-section of the metatarsal heads in a foot with a plantarflexed second metatarsal is illustrated. When the forefoot is close to contacting with the ground, but still is non-weightbearing, the plantarflexion deformity of the 2nd metatarsal is obvious (left). However, once the forefoot becomes weightbearing, the increase in ground reaction force (GRF) that occurs at each of the metatarsal heads will be particularly increased at the 2nd metatarsal head (middle) which may cause injuries to the osseous and/or soft tissue structures of the 2nd metatarsal or 2nd metatarsophalangeal joint. To treat the increased compression forces and stresses at the 2nd metatarsal head, a foot orthosis may be designed to increase the GRF plantar to the 1st, 3rd, 4th and 5th metatarsal heads and decrease the GRF plantar to the 2nd metatarsal head (right). This redistribution of GRF on the plantar foot, away from high pressure areas toward lower pressure areas, is the most likely mechanism behind the ability of foot orthoses to reduce pathologic pressures away from specific areas of the plantar foot.
Foot Orthoses Reduce Plantar Forces and Pressures

Research on the ability of foot orthoses to reduce the forces and pressures on injured or painful areas of the plantar foot provides yet another therapeutic mechanical action of foot orthoses (Figure 2). In a prospective study of 151 subjects with cavus foot deformity, those subjects wearing custom foot orthoses after 3 months showed significant decreases in foot pain, increases in quality of life and showed three times the forefoot plantar pressure reduction when compared to sham insoles. In 42 subjects with metatarsalgia, foot orthoses were found to not only decrease the metatarsal head pain but also significantly decrease the force impulse and peak pressure at the metatarsal heads. Significant reductions in plantar pressures and loading forces were shown in another study that measured the ef-
effects of foot orthoses on both normal and RA subjects. In 81 patients with Type II diabetes, maximum peak plantar pressures were reduced by 30% with foot orthoses and in 34 adolescent Type I diabetic patients both peak pressure and pressure-time integral was reduced while wearing foot orthotics. In a study of eight patients with plantar neuropathic ulcerations that had become healed with custom foot orthoses, it was found that their custom foot orthoses significantly reduced peak vertical pressure, reduced the pressure/time integral and increased the total contact surface area versus the no-insole condition. In another study using computer-simulated three-dimensional finite element analysis of a foot exposed to different orthosis constructions, orthosis shape was found to be more important in reducing peak plantar pressures than was orthosis stiffness.

Conclusion
Foot orthoses have been used for well over a century by clinicians as a means to reduce pain, improve gait mechanics and heal injury to the foot, lower extremity and lower back. There is considerable research evidence that supports the therapeutic efficacy and significant mechanical effects of foot orthoses on standing, walking and running activities. Theoretical explanations as to how foot orthoses actually produce their therapeutic and mechanical effects have been previously proposed and are being continually refined as exciting new research evidence is brought to light and discussed in academic forums. There is great promise for increased understanding and further development of foot orthoses as a valuable therapeutic tool in the treatment of mechanically-based musculoskeletal injuries for the athletic and non-athletic population of today and for future generations. PM

Editor's Note: The following list of references is for all three parts of Dr. Kirby's article. Part 1 appeared in September 2014; part 2 appeared in February 2015.

References
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Dr. Kirby is an Adjunct Associate Professor, Department of Applied Biomechanics California School of Podiatric Medicine, Oakland, California and Director of Clinical Biomechanics, Precision Intricast Orthotic Laboratory in Payson, Arizona.