Biomechanical Evaluation of the Efficacy of External Stabilizers in the Conservative Treatment of Acquired Flatfoot Deformity

Carl Imhauser¹, Nicholas A. Abidi, M.D.², David Frankel³, Sorin Siegler, Ph.D.¹
¹Drexel U., Dept. of Mechanical Engineering and Mechanics, Philadelphia, PA/USA
²Dominican Hospital, Orthopaedic Surgeons of Santa Cruz, Santa Cruz, CA/USA
³Thomas Jefferson University, Philadelphia, PA/USA

Introduction

Pes planus or flatfoot is the most common foot pathology in patients of all ages. The National Center for Health Statistics reports that 4,621,000 Americans complain of dynamic and/or structural flatfoot deformity every year.¹ Conservative treatment modalities for these pathologies include ankle braces and in-shoe orthoses to relieve pain and improve function. Approximately $410,000,000 are spent on these foot treatment products annually.² The rationale for the use of external stabilizers is that they prevent further collapse of the medial longitudinal arch by passively stabilizing the arch during both static and dynamic activities such as standing and walking. Despite the wide clinical use of ankle braces and in-shoe orthoses, the efficacy of these devices in achieving the functions described above has not been fully demonstrated. “Most reasoning for their use is anecdotal, with a lack of scientific evidence to support the claims of practitioners.”³

This study has two main goals: 1) Quantify the nature of the effects of flatfoot deformity on both the medial longitudinal arch and hindfoot. 2) Quantify and compare the efficacy of various ankle braces and in-shoe orthoses in stabilizing the hindfoot and medial longitudinal arch in a cadaveric model of acquired adult flatfoot deformity. The combination of independent analysis of hindfoot kinematics and arch kinematics with simultaneous measurement of plantar pressure distribution provides a unique approach to address both of these issues.

This study addressed the following hypothesis: Semi rigid foot and ankle orthoses provide passive stabilization to both the hindfoot and medial longitudinal arch, while in-shoe orthoses stabilize only the medial longitudinal arch and ankle braces only provide lateral support to the hindfoot.

Methods

Experiments were conducted on six fresh-frozen cadaveric lower limbs. Six different braces were tested including 2 in-shoe-orthoses, the UCBL, the Molded Ankle Foot Orthosis (MAFO), 3 ankle braces, the Air/Gel Stirrup Ankle Brace™ (EBI Inc., Parsippany, NJ), Active Ankle™ (EBI Inc.), and the Ascend Ankle Bracing System™ (EBI Inc.). and 1 molded ankle-foot orthotic the Arizona Brace™. The experimental system consisted of a loading frame interfaced to a tensile testing machine, which applied an axial load equal to half body weight through the tibia/fibula. Displacement of the bones comprising the hindfoot and the medial longitudinal arch was recorded through an optoelectric kinematic system (WATSMA R, Northern Digital Inc., Waterloo, Canada), while the pressure created under the foot was measured through a foot pressure distribution system (emed, Novell Inc., St. Paul, MN). Three conditions were tested: intact, unbraced; flatfoot, unbraced; and flatfoot, braced. Flatfoot deformity was created by sectioning the main support structures of the medial longitudinal arch: the plantar aponeurosis, long plantar ligament, spring ligament and the anterior deltoid ligament.⁴

Hindfoot kinematics were quantified by monitoring the six-degree-of-freedom motion at both the ankle and subtalar joints and across the ankle joint complex. Motion was described using the Grood and Suntay parameters.⁵ Arch kinematics were analyzed from a sagittal projection of the bones constituting the arch (Figure 1).

A separate repeated measure analysis of variance (RMANOVA) (p < 0.05) was performed on the five parameters used to quantify the medial longitudinal arch and the 18 parameters used to quantify the hindfoot. The results indicated if there were significant differences between each brace. Following the ANOVA tests, paired t-tests were performed at a significance level of p < .05 to identify the braces that were significantly different from each other.

Results and Discussion

Flatfoot deformity altered hindfoot kinematics at the ankle joint, subtalar joint, and across the ankle joint complex. At the ankle joint complex, the calcaneus everted. At the ankle joint, the talus plantarflexed, everted and rotated. At the subtalar joint, the talus plantarflexed on the calcaneus. The motion occurring in other joint parameters was inconclusive.
Flatfoot Deformity also resulted in altered medial longitudinal arch kinematics. It was found that the angles of both the calcaneus and first metatarsal decreased with respect to an axis oriented from the center of the calcaneus to the midpoint of the bases of the first and second metatarsals. Flatfoot deformity also caused translation in the bones of the medial longitudinal arch. Specifically, the height of the talus and medial cuneiform decreased (Figure 1). Minimal change in the location of the center of pressure occurred after flatfoot deformity, but the pressure distribution and area distribution on the plantar aspect of the foot was altered. (Figure 2)

Statistically significant differences between in-shoe orthoses and ankle braces were found in 3 hindfoot parameters. It was found that the in-shoe orthoses, including the Arizona, aided to dorsiflex (indicated by a positive value for a tib-cal in Table 1) and invert the calcaneus (indicated by a positive value for β tib-cal in Table 1) at the ankle joint complex. At the talocrural joint, in-shoe orthoses, including the Arizona, dorsiflexed the talus (indicated by a negative value for a tib-tal in Table 1).

Furthermore, in-shoe orthoses acted to stabilize the medial longitudinal arch by restoring several parameters (indicated by positive values in Table 2). The orthoses acted to restore the angle of the calcaneus and first metatarsal, the height of the talus and medial cuneiform. No ankle brace had a significant effect on the restoration of the original orientation of the navicular. (Table 2)
Both in-shoe orthoses and semi-rigid foot and ankle orthoses acted to partially restore several parameters used to describe the geometry of the hindfoot and the geometry of the medial longitudinal arch in a flatfoot. These devices, which passively support the plantar aspect of the foot, aided in restoring the parameters that are characteristic of a non-pathologic foot. Ankle braces minimally restored the geometry of the hindfoot and the arch in a flatfoot. Ankle braces did not restore arch or hindfoot geometry in a flatfoot by laterally stabilizing the hindfoot.

Acknowledgements

EBI Medical Systems Inc.
Novel Inc.
Ken Gavin, C.O.

References

7. Peterson, K.S.: Advice to Help Keep You Stepping Lively. USA Today, June 20, 1994, p.4D.