EFFECTIVENESS OF ORTHOSES IN CONTROLLING REARFOOT MOTION IN A GROUP OF SUBJECTS WITH REARFOOT VARUS

Orna Donoghue and Andrew Harrison
Department of Physical Education and Sports Science,
University of Limerick, Limerick, Ireland

This study examined the effectiveness of orthoses and triplanar wedges in controlling rearfoot motion compared to barefoot and shod conditions. Five male subjects were videotaped running on a treadmill at 3.8 m.s-1 under the four conditions (barefoot, shod, orthoses and wedge). A three-dimensional analysis was performed using the Peak Motus Analysis system. Both anti-pronation devices (orthoses and wedge) reduced motion compared to the barefoot condition, but this is not as relevant to everyday living as little activity takes place when barefoot. Neither device significantly controlled any variables compared to the shod condition although the orthoses did significantly increase the eversion angle at heel strike. It was concluded that while the devices are not effective prior to contact, they is a tendency towards a reducing effect on motion during stance.

KEY WORDS: pronation, orthoses, wedge.

INTRODUCTION: The subtalar joint (STJ) is a triplanar joint (Bristow, 1996) which functions to provide shock absorption at heelstrike, a rigid lever for takeoff and enable effective movement to take place (Hamill & Knutzen, 1995). In weight-bearing, STJ pronation involves calcaneal eversion (EV), talar abduction (ABD) and talar dorsi-flexion (DF). These movements occur in the frontal, transverse and sagittal planes, respectively, accompanied by internal rotation of the leg. Supination involves the opposite actions (Bristow, 1996).

Rearfoot varus occurs when the rearfoot is inverted to the supporting plane causing the foot to strike the ground in a supinated position. This is a very common condition, characterised by compensatory pronation, exceeding the normal range defined by Root et al. (1971). This may in some cases lead to clinical overuse injuries such as patellofemoral pain, Achilles Tendinitis, shinsplints, lateral compartment syndrome and plantar fasciitis (Stacoff et al., 2000a). However, there is no evidence to suggest that this is any more than a risk factor (Payne, 1999). The use of orthoses as a complementary treatment for these injuries has increased in recent years. Anecdotal and subjective reports on pain relief and symptom resolution are very positive but scientific evidence concentrating on actual changes in rearfoot motion remains equivocal (Heiderscheit et al., 2001).

The mechanisms by which orthoses are effective are not well understood. The devices are comprised of an arch support and a wedge. This study aims to isolate the wedge and compare its effectiveness in controlling rearfoot motion with that of the whole orthoses. It also examines transverse plane motion as it has been speculated that this may be critical in the occurrence of injuries (Areblad et al., 1990).

METHOD:

Subjects and Set-Up: Five healthy, male volunteers (mean age 26 10.5 years, mass 79.6 16.5 kg, height 1.77 0.1m) consented to participate in the study, which had received ethical approval from the University Ethics Committee. All subjects participated regularly in sport and had fully compensated, rearfoot varus resulting in clinical symptoms of the left limb. A collaborating podiatrist prescribed orthoses to control the compensatory pronation. Two measures (navicular drop and valgus index) were taken of the left foot to verify a rearfoot varus condition in all subjects. Three retroflective markers were placed on the posterior lower leg (on medial and lateral belly of gastrocnemius and proximal aspect of Achilles tendon), three on the rearfoot (medial and lateral lower borders of calcaneus and Achilles tendon) and one on each of the lateral knee joint, lateral malleolus and tuberosity of the fifth metatarsal. All subjects ran in their own shoes on a treadmill under 4 conditions - (1) barefoot, (2) shoes only, (3) shoes with orthoses and (4) shoes with wedges. The wedges were 4mm steeper than the orthoses and were affixed to the sole of the shoe. This isolated the posting aspect of the orthoses eliminating the effect of the arch support.

Video Analysis: Two Panasonic genlocked DPH800 S-VHS video cameras operating at a sampling frequency of 50 Hz were set up, one situated directly behind the athlete, the other to the left hand side. The Peak Performance 17 point calibration frame and the Direct Linear Transformation (DLT) Equations were used to facilitate three-dimensional analysis of lower limb kinematics. A static trial with the STJ in neutral position during weight-bearing was obtained for each subject in each condition. Dynamic trials were performed at a speed of 3.8 m.s-1 (13.7 km.hr-1). The measurements allowed movement relative to neutral position to be obtained.

Data Analysis: The Peak Motus 6.0 video analysis system (Peak Performance Technologies, Englewood, CO, USA) was used to digitise five footfalls for each condition. Smoothing and data calculations were carried out using a general cross validated quintic spline algorithm. Data was then time normalised from Heel strike (HS) to Toe off using a cubic spline in Matlab. HS angle, range of motion (ROM) and peak angles were examined as these parameters are related to injury and are affected by shoe modifications (Stacoff et al., 2000a). ROM was defined as the extent of movement in each plane from HS to maximum deflection. Peak angles were calculated as the sum of HS angle and ROM. The frontal and sagittal plane data was analysed in SPSS 10.0 using a General Linear Model (GLM) multivariate repeated measures ANOVA. The number of conditions (4), trials (5) and measures (HS and ROM) were defined. A significance level of p=0.05 was chosen.

RESULTS AND DISCUSSION: All subjects displayed the expected general pattern of rearfoot motion during stance (Bristow, 1996).

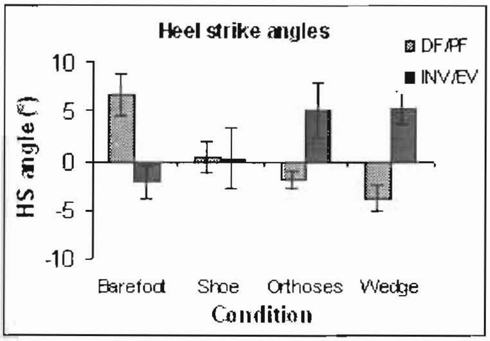
Sagittal Plane Motion: The data shows that the shoe is the major source of control at HS with the orthoses and wedge providing additional effects (see Table 1). The raised heel could explain the increased DF with the orthoses but it is not clear why the wedge increases this further. The shoe needed the anti-pronation devices to significantly decrease the ROM compared to the barefoot condition. The orthoses and wedge appear to be equally effective in controlling sagittal plane motion, implying that it is the posting aspect of the orthoses that is effective. The decreases in ROM should help in decreasing the range of pronation, however, the connection between and the lack of control over the initial contact angles and peak angles may pose problems in injuries such as Achilles Tendinitis and plantar fasciitis (Shorten, 2000).

Table 1 Average values for selected variables in sagittal and frontal plane motion.

	Sagittal plane motion (-ve = DF)					Frontal plane motion (-ve = INV)				
Cond.	HS (°)		ROM (°)		Peak DF (°)	HS (°)		ROM (°)		Peak EV (°)
	Mean	S.E.	Mean	S.E.	Mean	Mean	S.E.	Mean	S.E.	Mean
Barefoot	6.7	2.1	24.0	2.7	-17.3	-2.2	1.7	11.1	1.4	8.9
Shod	0.4a	1.7	20.1	1.4	-19.7	0.2	3.1	25.7a	3.2	25.9
Orthoses	-1.9a	.8	17.8a	2.2	-19.7	5.1a b	2.8	19.1a	2.4	24.2
Wedge	-3.8a	1.2	17.6a	2.3	-21.4	5.4a	1.8	11.2	7.1	16.6

a = significant difference from barefoot condition (p<0.05)

b = significant difference from shod condition (p<0.05)



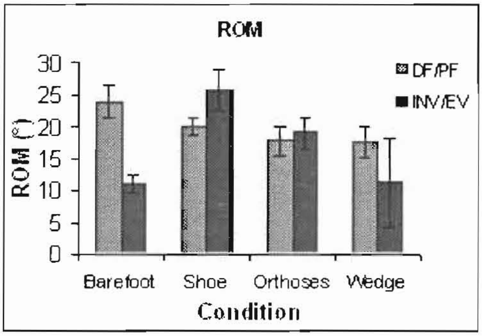


Figure 1 & 2: Group mean and standard error for sagittal (DF/PF) and frontal (INV/EV) plane heel strike angle and ROM for all conditions.

Frontal Plane Motion: The orthoses and wedge increased EV at HS compared to barefoot and shod conditions. The orthoses did not significantly reduce EV ROM (p=0.06) compared to the shod condition. The wedge massively reduced ROM by 14 , exceeding values reported by Johanson et al. (1994). This suggests that the arch support in the orthoses may hinder rearfoot control in the frontal plane. The decrease of 1.7 observed here in peak EV, when orthoses were used corresponds to a decrease of 1 to 3 , found by Stacoff et al. (2000b), but conflicts with Johanson et al. (1994) who found no reduction. The low wedge value, while influenced by the reduced ROM, supports the use of wedges in controlling rearfoot motion. However, the large standard errors in the wedge data emphasises the individual and unsystematic response by this device and should be noted when looking at the results.

Transverse Plane Motion: The rotations obtained in this plane were highly variable and did not allow a statistical analysis to take place.

The most significant sagittal plane effects were seen when a combination of the shoe and pronation control devices were used. The wedge appears to have an equal or greater influence on frontal plane motion than the orthoses compared to barefoot and shod conditions. This suggests that the posting may be a more important aspect of their design than the arch support. However, neither the orthoses nor wedge display systematic changes in motion relative to the shoe, as there is quite a lot of inter-subject variability. The results suggest that both devices had an effect on reducing the motion of the foot during stance compared to the shod condition, although this was not statistically significant.

Frontal plane motion was not as consistent or as accurate as sagittal plane motion, and this was possibly due to marker placement relative to camera set-up. There were problems in accurately identifying HS and toe-off events given that subjects included both rearfoot and forefoot strikers. This has implications for the measurements of rate of pronation, time it takes to reach maximum values or percentage time spent in pronation. The static tests and prescription of orthoses relied on obtaining STJ neutral position, although the validity of this has been questioned (Heidersheit et al., 2001). The use of skin and shoe mounted markers may also have overestimated the variables measured.

CONCLUSION: Both anti-pronation devices displayed a tendency to reduce sagittal and frontal plane ROM of several rearfoot variables compared to the shod condition. However, this was not significant at $p<0.05$ due to the high level of inter-subject variation. Several changes are proposed for future research. Rearfoot varus is a general term used to describe a number of more specific deformities that may cause compensatory pronation. These specific conditions may include: subtalar varus, tibial varum and in some cases, ankle equines. Greater control should be exercised in the selection and classification of subjects with respect to their specific deformity to ensure similar movement patterns and mechanisms of injury. Transverse plane motion should be examined to determine its influence and relation to injury. As most activity takes takes place when wearing shoes, it is possible that the orthotic prescription should be based on restoring individuals to the STJ neutral position obtained when shod. The effectiveness of the posting aspect and the arch support should also be assessed further to determine which aspect is most responsible for controlling excessive rearfoot motion. Future research examining the difference between these devices could then provide assistance in prescribing the most effective interventions for specific problems.

REFERENCES

Areblad, M., Nigg, B.M., Ekstrand, J., Olsson, K.O., & Ekstrom, H. (1990). Three-dimensional measurement of rearfoot motion during running. J. Biomechanics, 23(9), 933-940.
Bristow I. (1996) Foot function: an introduction to normal and abnormal biomechanics during gait. Inter Medica, 2(5), 8-11.
Hamill, J., & Knutzen, K.M. (1995). Biomechanical Basis for Human Movement. Media: Williams & Wilkins.
Heiderscheit, B., Hamill, J., & Tiberio, D. (2001). A biomechanical perspective: do foot orthoses work? British Journal of Sports Medicine, 35(1), 4-5.
Payne, C.B. (1999). Is excessive pronation of the foot really pathologic? American Journal of Podiatric Medicine, 33(1), 7-9.
Root, M.L., Orien, W.P., Weed, J.H., & Hughes, R.J. (1971). Biomechanical Examination of the Foot - Volume 1. Los Angeles: Clinical Biomechanics Corporation.
Shorten, M.R. (2000). Running shoe design: protection and performance. In D. Tunstall Pedoe (Ed.), Marathon Medicine (pp 159-169). London: Royal Society of Medicine. Available from: http://www.biomechanica.com/pdfs/Shorten%20Marathon.pdf
Stacoff, A., Nigg, B.M., Reinschmidt, C., van den Bogert, A., & Lundberg, A. (2000a). Tibiocalcaneal kinematics of barefoot versus shod running. Journal of Biomechanics, 33, 1387-1395.
Stacoff, A., Reinschmidt, C., Nigg, B.M., van den Bogert, A., Lundberg, A., Denoth, J., & Stussi, E. (2000b). Effects of foot orthoses on skeletal motion during running. Clinical Biomechanics, 15, 54-64.