The scientific basis for the use of biomechanical foot orthoses in the treatment of lower limb sports injuries – a review of the literature

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While it is documented that many overuse injuries of the lower limb can be relieved with the use of biomechanical foot orthoses, what remains unclear is how an orthosis can produce this effect. A review of the literature indicates that biomechanical orthoses will reduce rearfoot movement, but the effect on knee function is negligible and the clinical significance of excessive rearfoot movement is yet to be proven. While many athletes may potentially benefit from the use of biomechanical orthoses, further research is necessary to justify and, if indicated, promote the use of biomechanical foot orthoses by athletes suffering from overuse injuries.

Keywords: Orthosis, lower limb overuse injury

The application of biomechanical principles to the locomotor system of the human body has provided an alternative and seemingly effective conservative treatment for sports injuries¹⁻³.

The biomechanical approach seeks to determine abnormal position or function of the joints of the lower limb and foot^{4,5}. It is proposed that such abnormality will give rise to a number of lower limb injuries. Conditions such as excessive pronation of the foot are considered for instance to cause muscle overuse syndrome in the calf and pain in the anterior aspect of the knee^{1,2}.

An in-shoe biomechanical orthosis (see Figure 1) is usually prescribed to resist excessive pronation of the foot and restore normal alignment to the entire lower limb. The following literature review examines the scientific support for the use of biomechanical foot orthoses in sports medicine. To date research into the effect of functional orthoses falls into a number of key areas:

1. the effect of orthoses on overuse injury^{2,6};
2. the effect of orthoses on knee position and function^{1,7-13};
3. the effect of orthoses on rearfoot movement^{1,3,15-18}.

Figure 1. An in-shoe biomechanical orthosis. The rearfoot and forefoot wedges or posts are intended to hold the foot close to its neutral position

Effect of orthoses on pain related to overuse injury

Sperryn and Reestan⁶ performed a 42-month follow-up of 50 athletes with previously resistant lower limb overuse injury who had been prescribed orthoses. Complete relief was claimed by 56%, 8% were improved, while 30% were no better.

The athletes included in the study complained of a number of symptoms including anterior knee pain, foot pain, Achilles tendinitis and ankle sprains. The weekly running distances in the subjects ranged from less than 20 miles a week to more than 60 miles, the majority of subjects however exceeded 60 miles a week. The subjects were drawn from a large group of sports injury clinic patients but were selected for the study because they had proved resistant to conventional therapies such as rest, medication and physiotherapy.

In Donatelli *et al.*'s 1988 study of 81 subjects who had worn orthoses from 3 months to 2 years², 53 subjects responded to a questionnaire evaluation of their progress with orthoses. Relief from pain was reported by 96% while 52% said they would not

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leave home without the orthoses in their shoes. Unfortunately neither the training levels of the athletes nor the reasons why they were prescribed orthoses were stated.

Axe and Ray¹⁹ used biomechanical orthoses in the treatment of ten athletes with resistant sesamoiditis. While eight of the subjects had undergone a variety of previous treatment including cortisone injection, metatarsal padding and below knee casting, symptoms had persisted. Once the biomechanical orthoses were prescribed no further practices or competitions were missed by any of the athletes and at 18-month follow-up, eight of the ten subjects had sufficient symptom relief that surgical excision of the sesamoids could be avoided.

The findings of these studies, along with the widespread prescription of orthoses in sports medicine, led directly to a series of experiments which sought to determine the effect of orthoses on lower limb position and function.

Effect of orthoses on knee position and function

Cavanagh and Edington⁷ studied knee movement on an unspecified number of treadmill runners who were fitted with 10° varus, 10° valgus and neutral shoe midsoles. Little change in the amount, or the timing of knee flexion and extension was detected.

Cavanagh and Edington⁷ found this consistent with the work of Lafortune⁸, who used a system of intracortical pins to measure lateral movement of the patella in subjects wearing 10° varus, 10° valgus and neutral midsoles. The greatest change in patellar position was just 1.6 mm.

Similar work was carried out by Bates *et al.*¹ who recorded maximum knee flexion and patella internal rotation in six runners who ran on a treadmill while barefoot, in shoes, and in shoes with orthoses. No significant difference was found between any of the groups tested.

Eng and Pierrynowski used kinematic analysis to determine the effects of foot orthoses on transverse, frontal and sagittal plane movement of the knee in subjects with patellofemoral pain syndrome^{9,10}. Movement in the transverse and frontal plane was significantly reduced during heel strike and the midstance phase of walking, no significant effect was noted in the sagittal plane. The orthosis had no influence on knee movement during the push off phase of walking, though frontal plane movement of the knee was reduced in the swing phase. In running subjects, the only significant effect of orthosis was noted during the push off phase, when the orthosis reduced both frontal and transverse plane movement of the knee. Clearly the orthosis affected the knee differently in walking and running. The effect of the orthosis on the subject's patellofemoral pain was not described.

Foot orthoses were found by D'Amico and Rubin¹¹ to have a significant influence on the quadriceps (Q) angle. The Q angle is measured by determining the centre point of the patella and drawing a line to the anterior superior iliac spine proximally and through

Figure 2. The quadriceps (Q) angle. An excessive Q angle may cause patellar malalignment, the Q angle has been shown to be reduced by a functional orthosis

the tibial tubercle distally (Figure 2). A high Q angle is thought to be a significant cause of patellar malalignment leading to retropatellar pain. Normal Q angles range from 8° to 10° in males and 12° to 16° in females¹². A highly significant reduction of the Q angle was found to occur when orthoses were positioned beneath the feet of 21 standing subjects. The mean Q angle being reduced from 17.6° to 11.6°.

Unfortunately, the repeatability of D'Amico and Rubin's¹¹ measuring technique, involving a short-armed goniometer which did not overlie the points of anatomical reference, was not tested or reported, nor were the subjects used in the study knee pain sufferers, so the relevance to the condition remains uncertain.

Lefebvre and Boucher¹³, measured the effect of medial wedging of the foot on the Q angle of the knee with two-dimensional video analysis. While the Q angle was significantly reduced in static trials, there was no significant effect in the dynamic situation. Doubling the thickness of the medial wedge under the foot did not produce any further reduction of the Q angle. Lefebvre and Boucher's work indicates that while orthoses significantly reduce the Q angle of the knee in standing subjects, that effect is lost as soon as those subjects begin to move.

Effect of orthoses on the rearfoot

Rearfoot movement is believed to indicate the amount of subtalar joint pronation occurring within a foot. In normal circumstances, the subtalar joint should pass from a position of 2° supination just before heel contact to 4° of pronation at midstance⁵.

Excessive angles of subtalar joint pronation, or excessive periods of pronation and abnormality of velocity of subtalar joint pronation, is thought to be associated with a range of running injuries¹⁴.

Bates *et al.*¹ took six runners with a history of lower limb injury. Orthoses were prescribed and subsequently worn for at least 1 year, the subjects were then asked to run on a treadmill while their rearfoot movements were recorded with a high-speed cine camera.

Orthoses significantly reduced both the period and the amount of maximum pronation by reorienting the rearfoot relative to the running surface.

In a similar study of 11 selected subjects with no leg or foot pain, Smith¹⁵ found that soft and semirigid orthoses reduced rearfoot eversion by 1° while the subjects ran at 7-min mile pace on treadmills. The rate or velocity of rearfoot movement was more significantly affected, being reduced by 15%.

Kelley and Birke¹⁶ found a significant decrease in calcaneal eversion when orthoses were used by 21 subjects of mean age 30 years with a minimum of 5° calcaneal eversion in stance. The reduction in the calcaneal eversion, measured with three-dimensional kinematic analysis, was thought to result in a reduction of the movement generated by the opposing supinating muscles, hence the success of orthotic therapy in dealing with overuse muscle syndromes.

Common to all the studies reviewed, was the assumption that rearfoot movement can be determined by placing markers on the shoe. For this to be accepted, it must also be assumed that the foot does not move within the shoe, and the angle that the rearfoot makes relative to the supporting surface represents rearfoot inversion/eversion only; the superstructure above the foot having no influence at all.

Rogers and Leveau¹⁷ made an attempt to overcome some of these variables, 29 male runners were filmed running on a track while wearing their own orthoses and shoes. The proportion of support time spent in pronation, the maximum angular displacement in pronation and the angular velocity of pronation, were calculated from the calibrated film as the subjects ran barefoot, in shoes and in shoes with orthoses. The midline of the leg and heel of the shoe were marked in the normal way but the experimental deficiencies of this procedure were acknowledged. The biomechanical orthosis appeared to limit the maximum angular displacement in pronation and the support time spent in pronation for the left foot only. Throughout the rest of the study, the effect of orthoses and shoes did not achieve statistical significance.

In the information given about the structure and function of the athletes, it is clear some of the athletes pronated more than others, but were the orthoses more effective in some than others? Is the prescription of an orthosis (which should take into account factors like leg length difference), a standardized technique, and are the results noted in some studies the result of a superior prescription technique?

While recognizing the weaknesses inherent in these research studies, it does seem that they are all reporting the same finding – a biomechanical orthosis will restrict rearfoot pronation. But is this in itself a

relevant finding? What is the significance of rearfoot pronation?

Significance of rearfoot pronation

James *et al.*¹⁸ identified lower limb problems in 180 runners. Of these runners 58% exhibited rearfoot pronation on standing. On prescribing orthoses to 93 of them, 65 were able to return to their previous running programme³.

Vitasalo and Kvist³ compared the standing rearfoot position, the available passive range of rearfoot motion and the angular displacement of the rearfoot while running, for 13 pain free, long distance runners and 35 athletes with shin 'splint' type pain. A small but significant difference was found between the groups, the shin splint athletes demonstrating a greater range of motion in all measurements.

This finding was supported by Bates *et al.*¹ who similarly found increased rearfoot motion in injured athletes. It was perhaps significant that orthotic control provided by Bates *et al.*¹ to the injured runners, restored the mean value of maximum pronation to 7° which was similar to the maximum pronation in normal subjects wearing only a running shoe (7.2°).

Discussion

No single piece of research has yet proved the advantage of placing the foot in a supinated or neutral position rather than a pronated position. Such an investigation could take the form of a randomized controlled clinical trial which would take individuals with no foot pain and randomly assign them to receive an orthosis designed to either pronate or supinate the foot. If pronation of the rearfoot is a significant cause of lower limb pathology, a range of overuse injuries would be expected to develop as the subjects function on a pronated foot. The clinical significance of pronation will have been proven and the clinical value of an orthosis, (which has been shown by a number of studies to reduce pronation), will automatically have been confirmed.

The precedent for such a study has been created by the work of Sasaki and Yasuda²⁰. In comparing two groups containing 107 patients with early medial compartment osteoarthritis of the knee. Significantly greater pain relief was shown by 67 patients treated with indomethacin and a wedged insole, than by 40 patients treated with indomethacin alone. In order to achieve this effect, a valgus rather than a varus wedge insole was prescribed, the foot was pronated and the medial capsule of the knee was distended, articular loading was reduced and the osteoarthritic pain relieved.

While it must be emphasized that Sasaki and Yasuda's work established the benefit of antsupination orthoses in just one specific knee condition, it must also be noted that pain associated with an overuse injury was not a common side effect of the treatment. Just three of the 67 patients in the treatment group complained that pain had occurred elsewhere in the limb.

While many studies have found that orthoses reduce rearfoot eversion, no study has yet determined whether in-shoe orthoses actually achieve the stated aim of controlling foot function around the subtalar joint neutral position^{5,21}. In a study of 11 men and 19 women with no foot pain or obvious abnormality, McPoil and Cornwall found that the subtalar joint neutral position was never actually attained during the midstance phase of walking²². This finding has important implications for our understanding of the way in which in-shoe biomechanical orthoses affect foot and leg function, for up until now the objective of orthotic therapy has been to place the foot in a position that is never actually attained by normal feet.

The prescription and manufacture of functional orthoses has not been based upon scientifically proven principles. While a number of reports from different centres all around the world have indicated that orthoses are useful in the treatment of sports related injuries, little or no information has been given regarding the manner of the orthosis prescription. The two podiatric texts which have provided guidelines, present two markedly different approaches^{23,24}. This is a cause for concern especially as those same texts imply that an incorrectly prescribed orthosis may cause serious damage to the foot of the wearer. No single instance of long-term damage caused by the use of a functional foot

orthosis has been reported. This may be because patients simply remove an uncomfortable orthosis before any injury occurs. On the other hand could it be that as long as an orthosis is comfortable, it can be worn without risk, whatever the manner of its design?

The documented success of orthotic treatment among athletes must be considered in the light of present circumstances where there is no agreed standard for the prescription or manufacture of orthoses. Could it be that any sort of orthosis which prevents excessive movement of the foot will alleviate overuse muscle injury?

This last point may have already been confirmed. The actual prescription for a functional orthosis is largely determined by the subtalar joint neutral position measured clinically with a goniometer (Figure 3). A number of studies have demonstrated that this position is neither reliable nor valid^{25,26}.

In conclusion, biomechanical foot orthoses have been shown clinically to be useful in the treatment of some sports related lower limb injuries. The manner in which an orthosis works remains contentious, and many injured athletes remain unaware of the potential benefit of using biomechanical orthoses. Further research is necessary to justify and then, if indicated, promote their wider use.

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References

- 1 Bates BT, Osternig LR, Mason B. Foot orthotic devices to modify selected aspects of lower extremity mechanics. *Am J Sports Med* 1979; 7: 338-42.
- 2 Donatelli R, Hurlbert C, Conaway D. Biomechanical foot orthotics: a retrospective study. *J Orthop Sports Phys Ther* 1988; 10: 205-12.
- 3 Vitasalo JT, Kvist M. Some biomechanical aspects of the foot and ankle in athletes with and without shin splints. *Am J Sports Med* 1983; 11: 125-30.
- 4 Sgarlatto T. Compendium of Podiatric Biomechanics. San Francisco, California, USA: California College of Podiatric Medicine 1971.
- 5 Root ML, Orien WP, Weed JH. *Normal and abnormal function of the foot. Vol II.* Los Angeles, California, USA: Clinical Biomechanics, 1977.
- 6 Sperryn PN, Reestan L. Podiatry and the sports physician – an evaluation of orthoses. *Br J Sports Med* 1983; 17: 129-34.
- 7 Cavanagh PR, Edington CJ. What happens to the foot with an in-shoe orthosis? *Am Orthop Foot Ankle Soc Orthop Trans* 1989; 13: 655-6.
- 8 Lafortune M. The use of intra-cortical pins to measure the motion of the knee joint during walking. Pennsylvania University, USA: Unpublished PhD Dissertation, 1987.
- 9 Eng JJ, Pierrynowski MR. Effect of foot orthotics on the kinematics of the knee joint. *International Society of Biomechanics XII Congress*: 1989: 1007.
- 10 Eng JJ, Pierrynowski MR. Effect of temporary foot orthotics on the kinematics of the knee joint. *Physiotherapy Canada* 1989; 41(3 Suppl): 5.
- 11 D'Amico JC, Rubin M. The influence of foot orthoses on the quadriceps angle. *J Am Podiatry Association* 1986; 76: 337-40.
- 12 Hughston JC, Walsh WM, Puddu G. Patellar subluxation and dislocation. *Monographs in Clinical Orthopaedics* Philadelphia, USA: W.B. Saunders 1984: 1-191.

Figure 3. Measurement of the subtalar joint neutral position. The midpoint of the rearfoot and leg are marked and the angle formed between the two lines is measured

- 13 Lefebvre R, Boucher JP. Effects of foot orthotics upon the ankle and knee mechanical alignment. International Society of Biomechanics XII Congress, 1989: 1046.
- 14 Taunton JE, McKenzie DC, Clement DB. The role of biomechanics in the epidemiology of injury. *Sports Med* 1988; 6: 107-20.
- 15 Smith LS, Clarke TE, Hamill CL. The effects of soft and semi-rigid orthoses upon rearfoot movement in running. *J Am Podiatric Med Assoc* 1986; 76: 227-3.
- 16 Kelley DL, Birke JA, Gillis W. Frontal plane moment changes about the rearfoot with orthotic intervention. *Phys Ther* 1992; 72(Suppl): S78.
- 17 Rogers MM, Leveau B. Effectiveness of foot orthotic devices used to modify pronation in runners. *J Orthop Sports Phys Ther* 1982; 4: 86-90.
- 18 James SL, Bates BT, Osternig LR. Injuries to runners. *Am J Sports Med* 1978; 6: 40-50.
- 19 Axe MJ, Ray RL. Orthotic treatment of sesamoid pain. *Am J Sports Med* 1988; 16: 411-16.
- 20 Sasaki T, Yasuda K. Clinical evaluation of the treatment of osteoarthritic knees using a newly designed wedged insole. *Clin Orthop Rel Res* 1987; 221: 181-7.
- 21 Newell SG. Functional neutral orthoses and shoe modifications. *Physical Med Rehab Clin N Am* 1992; 3: 193-221.
- 22 McPoil TG, Cornwall MC. The relationship between subtalar joint neutral position and the pattern of rearfoot motion during walking. *Phys Ther* 1992; 72(Suppl): S77.
- 23 Philps JW. *The Functional Foot Orthosis*. Edinburgh, Scotland: Churchill Livingstone, 1991.
- 24 Anthony RJ. *The Manufacture and Use of the Functional Foot Orthosis*. S. Karger, Basel, Switzerland, 1991.
- 25 Elveru RA, Rothstein JM, Lamb RL. Goniometric reliability in a clinical setting. *Phys Ther* 1988; 68: 672-7.
- 26 Elveru RA, Rothstein JM, Lamb RL. Methods for taking subtalar joint measurements. *Phys Ther* 1988; 68: 678-81.

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