THE INFLUENCE OF FOOT ORTHOSES ON IN VIVO MIDFOOT SKELETAL MOTION DURING WALKING

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INTRODUCTION

It has previously been demonstrated that the influence of foot orthoses on in vivo skeletal hindfoot (tibio-calcaneal) motion during running was subject specific (Stacoff et al. 2000). I was speculated that the origin of the orthotic effects observed most likely was both mechanical and proprioceptive. Additionally, it was suggested that the orthotic effect might be more pronounced on midfoot and/or forefoot movements. Therefore, the aim of this study was to evaluate the effect of two types of orthoses on the midfoot skeletal (calcaneo-navicular) motion during locomotion.

MATERIAL AND METHODS

Eight subjects volunteered to participate in the study 1 female and 7 males age 39, S.D. 9 years, height 1.80, S.D. 0.1 m, weight 81, S.D. 13 kg. shoe size 43, S.D. 3 European sizes. During local anaesthesia Kirschner wires (K-wires, 2 mm) were inserted

Three-dimensional midfoot and hindfoot motion was determined using a motion analysis system (Qualisys, ProReflex, 5 cameras, 240 frs s^{-1}) and derived from bone mounted clusters of reflective markers during treadmill walking at preferred walking speed. The preferred walking speed was determined with photo cells during a series of trials during over ground walking.

Figure 1. K-wires inserted guided by X-ray in calcaneus (upper dark line) and navicula (lower dark line)

Hindfoot motion was determined as the relative tibio-calcaneal rotations and midfoot motion was determined as the relative calcaneo-navicular rotations. During local anaesthesia small pins made of Kirschner wire (K-wire, 50 mm long, 2 mm thick) were inserted about 25 mm in depth into: 1. the lateral epicondyle of tibia, 2. the upper part of the lateral wall of calcaneus and 3. the dorsomedial wall of the navicular bone of the right leg. On each of these pins clusters consisting of three reflective markers (marker diameter 19 mm and distance between markers 60 mm) were mounted. The K-wire in the navicular bone was inserted guided by X-ray to ensure a proper positioning and due to the dorso-medial direction of the inserted pin (fig. 1) the marker cluster on this pin was mounted via a small mechanical joint and thereby directed towards the dorso-lateral side of the foot. The bone orientations were referenced to their orientations during upright barefoot standing with full body weight on the foot. Footswitches (force sensing resistors) were mounted under the heel and the forefoot respectively. The three dimensional marker coordinates were obtained by direct linear transformation using the QTM-software (Qualisys®, Sweden). The coordinates were lowpass filtered at 4 Hz (4th order zero lag Butterworth filter) and the relative motion of the bones were calculated as Euler angles using Matlab® (Mathworks, USA).

The skeletal motion was recorded in the following four conditions: 1) barefoot, 2) wearing flat hard canvas shoes, 3) wearing the shoes and a heat moulded orthotic of the type SUPERSOLE fitted by a physical therapist and 4) wearing the shoes and an orthotic fitted by an orthopedic shoemaker from an ink foot print. The latter is a type of orthotic which commonly is prescribed to persons with painful hyperpronated feet. For each situation 10 step cycles were isolated using the footswitch signals and averaged.

The four situations were compared using a One way repeated measures ANOVA.

RESULTS

The subjects walked with an average speed of 5.2, S.D. 0.2 km hr^{-1}. Both the midfoot motion i.e. the calcaneo-navicular motion and the hindfoot motion i.e. the tibio-calcaneal motion was analyzed. The following three dimensional parameters were extracted from the reconstructed orientations of the bones. 1) the angles at heel contact, the angular range of motion (ROM) during the stance phase and 3) the total ROM during gait cycle. No systematic effects of shoe or the combinations of shoes and orthoses were found except for an increased ROM during the stance phase in tibio-calcaneal plantar-dorsiflexion direction wearing shoe+Supersole compared to barefoot walking. (19, S.D. 6 deg vs. 14 S.D. 5 deg, $p < 0.05$). However, a closer inspection of the angular traces revealed different individual effects of the shoes and the combinations of shoes and orthoses.

DISCUSSION

Since pronation of the foot most likely is a combination of tibio-calcaneal eversion and calcaneo-navicular eversion and dorsi-flexion and abduction we expected to find a shift of the bone orientations and ROMs in opposite directions if the orthoses have had a significant orthotic effect on the positioning and motion of the bones in the foot. The lack of systematic orthotic effects on both midfoot and hindfoot motion could be due to that not only direct mechanical action of the orthoses have an influence but also proprioceptive input which in turn may change the muscle activation pattern in the intrinsic foot musculature and in the muscles in the lower leg supporting the medial arch of the foot. However, it can not be excluded that the orthoses used in this study primarily has an unloading function i.e. the load under the foot is distributed and thereby improving the foot comfort, and that due to the qualitative way the orthoses normally are manufactured they are not precisely enough fitted to the individual foot functional anatomy and therefore not able to support the medial arch properly to correct for over pronation.

REFERENCES

Stacoff, A, et al. (2000). Effects of orthoses on skeletal motion during running, Clinical Biomechanics, **15**: 54-64.