# MIDFOOT MOTION AND ITS IMPLICATIONS FOR FOOTWEAR DESIGN

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## INTRODUCTION

A main aim of footwear design is to prevent musculoskeletal injury. Currently, there is a lack of knowledge and also uncertainty about the extent that foot motion can and should be controlled within a shoe. Concerns include the possibility that shoes might limit midfoot and hallux motion compared to the barefoot condition, requiring compensations at the ankle joint (Attwells and Smith, 2000) and similarly, that functional kinematic data obtained from a shoe can provide misleading information about the foot motion within (Reinschmidt et al., 1997). Some of the challenges in optimizing footwear impacts, are concerned with the problem of knowing what motion is occurring in the foot within the shoe.

It is possible that any (unwitting) constraint to the normal concomitant motion across several joints could lead to a focus of excessive and harmful stresses elsewhere in the kinetic chain. To date, most of the research into shoe effects has been directed towards control of the rearfoot to prevent injury (Nigg, 2001), rather than on accommodating normal motion in the midfoot and forefoot. However, footwear should probably not impede the normal motion relationships of the joints within the foot. Both the absolute and relative contributions of the individual joints of the normal adult foot under all possible loading situations are mostly speculated rather than completely understood. Therefore the aims of the current study were to describe motions representative of normal physiological positions of the foot, eg, when walking over uneven ground and during sports.

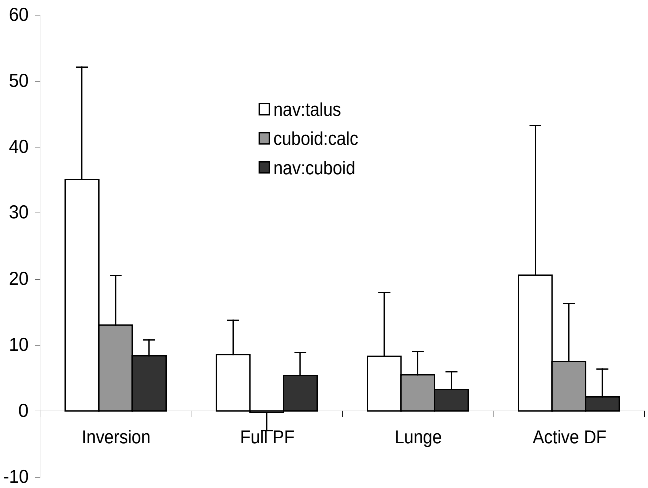
## METHODS

Rotation and translation of the rearfoot joints in normal subjects were calculated using radiostereometric analysis (RSA). Each of the relevant bones had been previously implanted with 3 or 4 tantalum markers (radio opaque) under local anaesthetic, utilising standard surgical procedures. Synchronised double X-ray exposures were made to calculate the bone positions relative to a calibration coordinate system, defined by a cage with tantalum markers. Ethical approval was granted by the Karolinska University Hospital ethics committee.

The subject stood with the examined foot within the calibration cage. X-ray exposures were obtained for the following positions: (i) neutral: a reference position with the subject standing straight and relaxed with weight evenly distributed between both feet, (ii) inversion (foot turned in), (iii) eversion (foot rolled out), (iv) plantarflexion (demi-pointe position), (v) active full dorsiflexion and (vi) lunge (passive dorsiflexion). Using RSA, individual joint rotations were calculated of the distal:proximal bone relative to the reference position: rotations about the X-axis (mediolateral axis) for the dorsiflexion and the plantarflexion, and Y and Z rotations for inversion and eversion. The joints examined were the: talotibial (talus:tib), talocalcaneal (calc:talus), talonavicular (nav:talus), calcaneocuboid (cub:calc), navicularcuboid (nav:cub), medial cuneiform:navicular and medial cuneiform:first metatarsal joints.

## RESULTS

For both the lunge and the active DF procedures, dorsiflexion motion occurred only in the tibio-talar joint, being 30º for the lunge and 19º for active DF. During the lunge, there was compensatory plantarflexion in the nav:talus joint (10º), calc:talus joint (6º) and the cub:calc (4º) joints.




Although most plantarflexion rotation during full range foot plantarflexion was at the talus:tibia joint, the total foot plantarflexed position was enabled by plantarflexion within the foot. There was 30º at the talus:tibia, 10º at the nav:talus, 6º at the calc:talus and 4º at the cub:calc joints.

Inversion was a notable feature of the midfoot joints in all positions, except for eversion. Even so, inversion occurred at the nav:cuboid during eversion for 2 of the 3 subjects. The resulting inversion rotations are presented in Figure 1.

**Figure 1**. Inversion motion occurring at three midfoot joints for 4 foot positions, mean ±SD

## DISCUSSION

Whilst there was a consistent joint response for most of the rotations and joints studied across the 3 subjects, some large SDs represent the inter-individual differences for normal function. For example, the range of inversion rotation that occurred during the lunge was 0.38º-19.04º. The implication for footwear for both scenarios, i.e. consistency and variability was that large rotations typically occur at the 3 midfoot joints examined about all three rotation axes.

Considered together, the 3 midfoot joints equip the midfoot for adaptability, by for example, enabling the lateral side of the foot to mould into a supinated position. What remains to be known is whether a shoe permits the necessary inter-bone motion within the foot, or constrains it to a detrimental extent. A subsequent study will investigate this question and also the motion of the foot joints relative to the shoe. This preliminary report is based on joint rotation data from 3 subjects who performed end of range foot positions in weight bearing. The final data set for this study will comprise 6/7 subjects.

## REFERENCES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