# Foot pronation in vivo – combined midfoot and hindfoot kinematics

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## INTRODUCTION

Tibiocalcaneal (hindfoot) mobility has previously been described in vivo as a measure of foot pronation (e.g. [1]). However, this measure does not include the possible contribution of midfoot motion to foot pronation. The aim of the present study was to describe the combined mobility of the hindfoot and the midfoot in vivo in relation to the level of foot pronation.

## METHODS

Fifteen volunteers participated in the study (4 females and 11 males). Age 43, SD 13 years, height 1.75, SD 0.1 m, weight 78, SD 13 kg, shoe size 42 SD 3 European.

The level of foot pronation was determined as the height of the medial arch of the foot during static loading (‘reference navicular height’) and the dynamic variation in this height (‘dynamic navicular drop’) during barefooted treadmill walking at 5.5 km $hr^{-1}$ was measured using a combination digital photography and electrogoniometry [2].

Three-dimensional hindfoot and midfoot motion was determined using a motion analysis system (Qualisys, ProReflex, 4 cameras, 240 frs $s^{-1}$) and derived from bone mounted clusters of reflective markers during barefooted treadmill walking at 5.5 km $hr^{-1}$ and a series of full range voluntary ankle-foot movements. 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 the orientations during upright standing with full body weight on the foot.

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

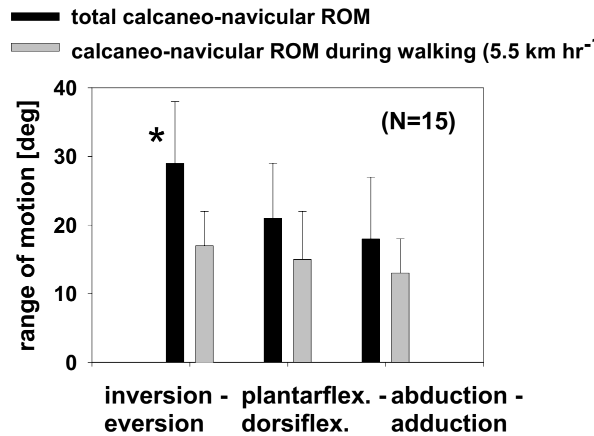


**Figure 2.** In vivo midfoot full range of motion (ROM) and ROM during walking (mean & SD). * = total inversion-

## RESULTS AND DISCUSSION

The preliminary analyses have demonstrated that the reference navicular height ranged between 30 and 60 mm (mean 44, SD 8 mm) representing a wide range medial arch architectures. The dynamic navicular drop ranged between 14 and 61% (mean 30, SD 14%) of the reference navicular height during walking. The total calcaneo-navicular range of motion (ROM) (Fig 2, black bars) was similar to the talo-navicular ROM previously described in vitro [3]. The largest total calcaneo-navicular range of motion was observed in inversion-eversion. During walking the calcaneo-navicular ROM was between 60 and 70 % of the total ROM (Fig. 2, grey bars) with no significant differences between the movement directions. It was expected that tibio-calcaneal eversion and calcaneo-navicular eversion and dorsi-flexion would be correlated to flattening of the medial arch of the foot. However, no significant correlations were found between the level pronation (dynamic navicular drop) and the ROM in any direction of tibio-calcaneal or calcaneo-navicular movement.

## CONCLUSIONS

Due to inter-individual variation in: joint geometry, ligament architecture and mechanical properties, architecture of muscle-tendon attachments, muscle strength and coordination it seems that foot pronation is achieved inter-individually through a wide range of combinations of mid- and hindfoot rotations.

## REFERENCES

1. Reinschmidt et al. (1997) Gait & Posture 6: 98 – 109.
2. Voigt M et al. (2005) XXth Congress of the International Society of Biomechanics
3. Ouzounian et al. (1989) Foot & Ankle 10:140 – 146.