

# THE RELATION OF FRONTAL PLANE ANKLE JOINT INSTABILITY AND SAGITTAL PLANE KINEMATICS AND KINETICS IN HEEL TOE RUNNING

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## INTRODUCTION

Frontal plane ankle joint eversion and inversion in the stance phase in running is a result of external moments from the vertical and medio-lateral ground reaction forces (GRF). The lever arm of the GRF to the ankle joint centre in the frontal plane was frequently discussed as a major factor of the amount of rearfoot eversion during early stance. The increased height of the joint centre through footwear with high midsoles was derived as the major factor for excessive calcaneal eversion and pronation (e.g. Nigg & Segesser 1992).

At the initial ground contact in heel toe walking or running the point of application of the GRF acting in the sagittal plane is located posterior to the ankle joint centre. The antero-posterior and the vertical ground reaction forces generate an external plantar flexion moment to the ankle joint resulting in an initial plantar flexion in the early phase of the foot ground contact during heel toe running. This initial plantar flexion of up to 15° in shod running occurs within the first 10 to 15% of the stance time (Reinschmidt et al., 1997). Due to the initial plantar flexion of the ankle joint the length of the muscle tendon unit of the triceps surae muscle (TS) should shorten. A rough estimate gives a shortening of e.g. the muscle tendon unit of the soleus muscle of about 1 cm within 20 to 30 ms which gives an average shortening velocity of the muscle tendon unit of about 0,5 ms<sup>-1</sup>. Due to the limited force production potential of the contractile unit of the TS at high contraction velocity (Hof, 2003) the shortening of the entire muscle tendon unit occurs in the Achilles tendon and produces a drop in the Achilles tendon force (ATF) immediately after the heel strike (see figure 1). This rapid drop in ATF with footstrike in heel toe running was also reported by Komi (1990) using the highly reliable buckle transducer technique.

During the early stance the contractile component of the TS is de-coupled from the calcaneus and cannot transmit force to the bone. Due to the fact that the most powerful inversion muscles like Mm. tibialis posterior (TP), flexor hallucis (FH) and flexor digitorum (FD) are also plantar flexor muscles they should underly the evaluated mechanism and are de-coupled from their respective insertion during the early stance in heel toe running; they loose their capacity for producing plantar flexion and inversion moments.

The lever arm of the GRF to the ankle joint in the sagittal plane in the early stance should play an important role to initiate the ankle joint de-coupling.

Therefore the purpose of this study was to investigate the influence of the sagittal plane lever arm in the early stance on the de-coupling mechanisms of the TS, the other plantar flexors and thus on the ankle joint instability in the frontal plane.

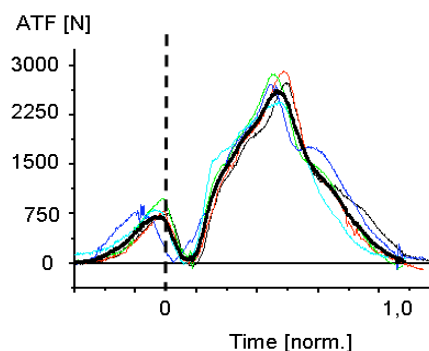
## METHODS

To investigate the effect of the lever arm of the GRF to the ankle joint in the sagittal plane twelve subjects run barefoot

and in shoes with different heel constructions. For each of the experimental conditions five runs (3.5 m/s) per subject have been carried out. The lower leg kinematics were recorded with a set of 12 high-speed cameras (Vicon, 250 Hz). GRF were sampled with two force plates (Kistler, 1250 Hz). In order to increase the accuracy of the calculation of the point of application the force in the early stance phase a pressure distribution platform (Emed, Novel) operating at 400 Hz was installed on top of the Kistler force platform.

## RESULTS AND DISCUSSION

The earlier performed study on Achilles tendon force in shod heel toe running indicated the described de-coupling in the early stance (see figure 1).



**Figure 1:** Achilles tendon force during the stance phase in shod running (time normalized) of five trials of one subject. The forces are measured using the optic fiber technique (Komi 1990). The vertical line indicates to moment the foot hits the ground.

Footwear and its heel construction influence the touchdown angle of the foot as already shown by De Wit (2000). The lever arm of the GRF to the ankle joint in the sagittal plane at heel strike was decreased in the barfoot condition by more than 50% in relation to the shod conditions. The time the GRF vector passes the ankle joint in the sagittal plane (transition time) and initiates the direction change of the external moment at the ankle joint in the sagittal plane was significantly influenced by the footwear/barefoot conditions. The initial plantar flexion was decreased by 9±2° in the minimum lever arm condition (barfoot) in relation to the shod conditions. Maximum eversion was significantly smaller in the barfoot condition than in the shod conditions. Frontal plane ankle joint instability is strongly related to the sagittal plane kinematics and kinetics in the early stance in heel toe running.

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