Influence of rearfoot kinematics during initial ground contact on knee joint loading in rearfoot running

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Introduction

The knee has been shown to be a common site of injury for runners whereas Patellofemoral Pain Syndrome (PFPS) is the most common of the injuries to this joint. High abduction and external rotation moments in the knee joint as well as knee abduction impulse are related to overuse injuries like PFPS [6,7].
In this context some sports physicians as well as coaches advocated forefoot running as "natural running" and promised a reduction of joint loads which should lead to the prevention of overuse injuries [1]. With reference to different running strike patterns it was shown that forefoot running compared to rearfoot running causes higher knee external rotation moments [3]. Regarding the peak power absorption in the MTP and ankle joint, forefoot running may overwork the gastrocsoleus muscle group and increase the risk for injury such as Achilles tendinitis [9]. Conversely, forefoot running reveals less peak power absorption and eccentric work at the knee compared to

rearfoot running, which may result in lower demands of the quadriceps muscle group [9]. It was concluded that forefoot running does not necessarily lead to a lower risk concerning the incidence and development of running related injuries. It is likely that the location of the injuries/complaints can be influenced by the strike pattern [3].
Now, it is postulated that a flat initial foot contact will contribute to the prevention of overuse injuries [2]. Currently, more runners, coaches, physicians and biomechanics than ever before debate about running technique and its influence on running performance as well as injury prevention [8].
The main goal of the present study was to determine the influence of rearfoot kinematics during initial ground contact on knee joint loads in rearfoot running.

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Material & Method

- **Test protocol**
  - Rearfoot running: 4.0±0.2ms^{-1} (controlled speed)
  - 5 valid trials for each subject
  - Synchronized kinematic und kinetic data collection
- **Kinematics**
  - 6-camera-VICON-system (200Hz)
  - High speed video systems (VOSSKÜHLER) from posterior and lateral (200Hz)
- **Kinetics** (ground reaction forces)
  - KISTLER-force plate (1000Hz)
- **Inverse Dynamics**
  - Body model of lower extremities [4]
  - 3 reflective markers per segment (pelvis, upper leg, lower leg, rearfoot and forefoot) (Fig. 1, Fig. 2)
  - Determination of anthropometrics
  - Calculation of 3-dimensional joint moments
- **Subject group** (n=19, practiced rearfoot strikers)
  - Age: Ø 33 ± 8 years
  - Body height: Ø 177 ± 4cm
  - Body mass: Ø 72 ± 6kg
  - Training volume: Ø 55 ± 58km
  - Training frequency: Ø 4 ± 2 units/week
  - Running experiences: Ø 15 ± 8 years
- **Statistics**
  - Descriptive statistics
  - Bivariate Correlations (Pearson's correlation coefficient)
- **Test vehicle** (Fig. 3)
  - adidas® Supernova Control

Fig. 1. Marker placement (1a) leg and (1b) test vehicle

Fig. 2. Definition of rearfoot angles with reference to the global coordinate system (gcs)
(2a) sole angle (sagittal plane)
(2b) heel angle (frontal plane)
(2c) displacement angle (transversal plane)

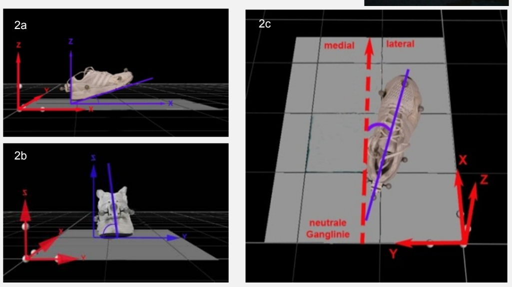


Fig. 3. Test vehicle

Results

- All rearfoot angles with reference to the global coordinate system (gcs) reveal for all three planes a high inter-individual variability, especially in the sagittal plane (Tab. 1, Fig. 4, 6)
- None of the rearfoot angles indicate a significant correlation coefficient with respect to the abduction and external rotation moments in the knee joint nor to the knee abduction impulse (Fig. 5)
- Exclusively the lower leg angle, which was analysed additionally, shows a moderate correlation (r=0.544*) with respect to the knee max. external rotation moment
  - A more vertically aligned lower leg during initial ground contact increases the knee max. external rotation moment

Tab. 1. Kinematic data [°] during initial ground contact (t0), with reference to the gcs

Parameter	Mean±SD	Range
Sole angle	23°±5	22°
Heel angle	9°±2	6°
Displacement angle	8°±4	16°
Lower leg angle	68°±5	20°

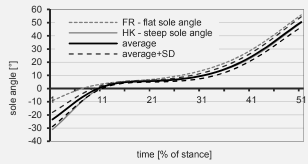


Fig. 4. Sole angle - average of 19 subjects and two extremes (flat and steep sole angle)

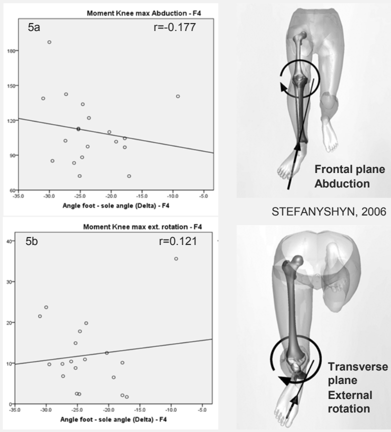
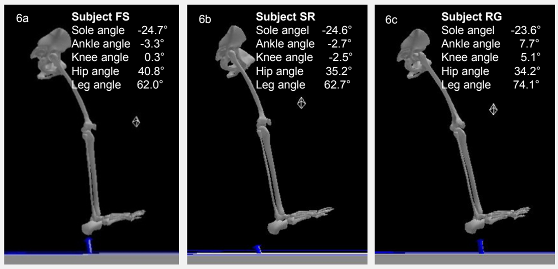


Fig. 5. Bivariate Correlations between sole angle and (4a) max. knee abduction moment and (4b) max. ext. rotation moment; with illustrations of the acting moments

Fig. 6. Selected samples of subjects with inter-individual adaptation patterns in the sagittal plane – similar sole angle, but different kinematics in the ankle, knee and hip joints. Especially the lower leg angle (with reference to the gcs) differs between subject FS (Fig. 6a) and subject RG (Fig. 6c). (values refer to the average of 5 trials, illustrations just represent one trial)



Discussion & Conclusion

The analyzed subject group exhibits strong inter-individual varying rearfoot kinematics during initial ground contact. The present data cannot confirm that the sole angle in terms of "steep versus flat" influences the knee joint load [2] and therefore the development of PFPS [6,7]. The alignment of the lower leg during landing seems to have an influence on the knee max. external rotation moment, but just a moderate one. However, this finding suggests, that a modification of the landing technique, particularly in the sagittal plane, in order to prevent overuse injuries, should not be limited to rearfoot kinematics. The whole kinematic movement chain from the foot up to the hip should be considered when giving recommendations for running style adaptations to prevent running related overuse injuries. Influencing variables could be:

- Individual running style/technique including individual adaptation mechanisms
- Fatigue, muscle activation including consideration of «Muscle Tuning Concept» [5]
- Step length and step frequency as well as running velocity

In order to determine the influence of running technique on the incidence of sport specific injuries and complaints, it is necessary to conduct combined prospective epidemiological field and laboratory studies. Independent of the running technique debate [8], it has been suggested that altering the strike pattern may decrease the risk of developing certain injuries [9].

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