DOES REARFOOT EVERSION ANGLE REPRESENT REARFOOT EXTERNAL EVERSION MOMENT DURING STANCE PHASE OF RUNNING?

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Rearfoot external eversion moment has been thought to contribute to overuse running injuries. Conventionally, the rearfoot eversion angle was used to evaluate the susceptibility of overuse running injuries. However, the relationship between the angle and moment has never been examined. Therefore, in this study, the relationship between the maximum rearfoot eversion angle and the maximum rearfoot external eversion moment during stance phase of running were estimated. As poor, not significant correlation obtained between these two variables, it can be assumed that the rearfoot eversion angle does not represent external eversion moment. From this result, it can be suggested that the use the kinetic variables such as external moment, is preferred to detect the susceptibility of overuse running injuries.

KEY WORDS: running, rearfoot eversion, angle, moment

INTRODUCTION: Rearfoot eversion motion is thought to be a potential cause of overuse running injuries. Conventionally, rearfoot eversion angle has been used to evaluate the susceptibility of overuse running injuries. This simplified measure has been widely spread over clinical field. A number of authors (Messier and Pittala, 1988; Willems et al., 2006) have reported that runners who suffer an overuse running injuries had a greater eversion angle. However, there are counter arguments by several researchers indicating a smaller eversion angle related to overuse running injuries (Duffey et al., 2000; Ghani Zadeh Hesar et al., 2009) or no relationship exists between the eversion angle and overuse running injuries (Noehren et al., 2013). Rodrigues et al. (2013) proposed the difficulty of pinpointing a direct relationship between kinematic variables such as rearfoot eversion angle and overuse running injuries. Ito et al. (2009) also suggested that rearfoot external eversion moment is a primary cause of the foot eversion motion and is likely risk factor for foot eversion-related overuse injuries. In general, it can be thought that overuse running injuries are caused by repeated motion at or exceeding the individual's joint ROM with additional load on the joint. Thus, the external moment that induces rearfoot eversion motion (Tsujimoto et al., 2015) is rather preferable parameter to evaluate the susceptibility of overuse running injuries than rearfoot eversion angle. To date, however, no studies have demonstrated the relationship between the external rearfoot eversion moment and the resultant rearfoot eversion angle.
The purpose of the present study, therefore, was to investigate the relationship between rearfoot eversion angle and rearfoot external eversion moment during stance phase of running. If the two parameters are high associated, the magnitude of rearfoot eversion angle can be used as a substitute parameter of the external moment inducing rearfoot eversion motion.

METHODS: Fourteen healthy adult men who demonstrated a consistent rearfoot strike pattern participated (mean age 22.1 ± 2.0 years; height 170.6 ± 4.8 cm; mass 64.1 ± 10.9 kg). All participants signed informed consent forms that had been approved by the ethics committee of a university.
Kinematic data were collected at 500 Hz using a 10-camera opto-electronic motion capture system (Vicon Nexus; Vicon Motion Systems, Oxford, UK). A force platform (Type 9281E; Kistler Instruments, Winterthur, Switzerland) embedded in the middle of a 30-m runway

recorded the ground reaction forces at 1000 Hz. The force platform and the motion capture system were synchronized electronically.
The marker locations used for analysis are shown in Figure 1. To restrict skin movement artefacts at heel contact, a thermoplastic plate was specially made for each subject and adhered tightly to the posterior surface of the heel. The HEE and HEE2 markers were then glued onto the plate, with the HEE marker placed 2 cm above floor level.
Target running speed was set at 3.30 m/s, allowing for a 5% margin (± 0.17 m/s). A trial was considered valid when the participants landed in the force platform without changing their natural running stride. Data from five valid trials were collected for each participant.
Longitudinal foot axis was defined as the HEE-TOE vector in the transverse plane when the foot was flat on the ground (sum of the height of STAL, LCA, HEE, HEE2, NAV, P1M, P5M, D1M, D5M, TOE, HLX was the minimum).
The rearfoot eversion angle was computed using the angle which is calculated by the shank vector (midpoint of MMA and ANK - midpoint of MKN and KNE) and calcaneus vector (HEE2 - HEE), then projected onto the perpendicular to the longitudinal foot axis (Figure 2).
The rearfoot external eversion moment were computed using the moment which is calculated by the cross product of the vector from the ankle joint centre (midpoint of MMA and ANK) to the COP and the vector of the GRF, then projected onto the plane perpendicular to the longitudinal foot axis (Figure 2).
Maximum value of the rearfoot eversion angle and maximum value of the rearfoot eversion moment were calculated in each trial. These parameters in five trials were averaged for each participant. A Pearson's product–moment correlation coefficient among participant was used to verify the relationship between rearfoot eversion angle and rearfoot external eversion moment.

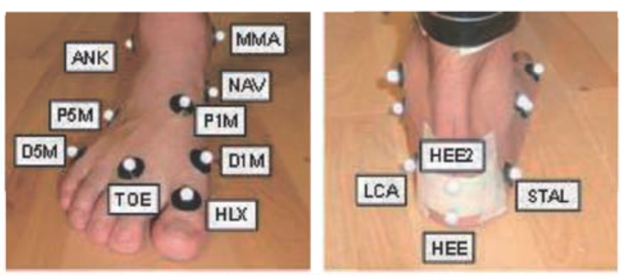

Figure 1: Marker locations: Medial and lateral malleolus (MMA, ANK), medial and lateral part of the calcaneus (STAL, LCA), lower and upper heel (HEE, HEE2), navicular bone (NAV), first and fifth proximal metatarsal heads (P1M, P5M), first and fifth distal metatarsal heads (D1M, D5M), medial point between the second and third metatarsal heads (TOE), and hallux (HLX).

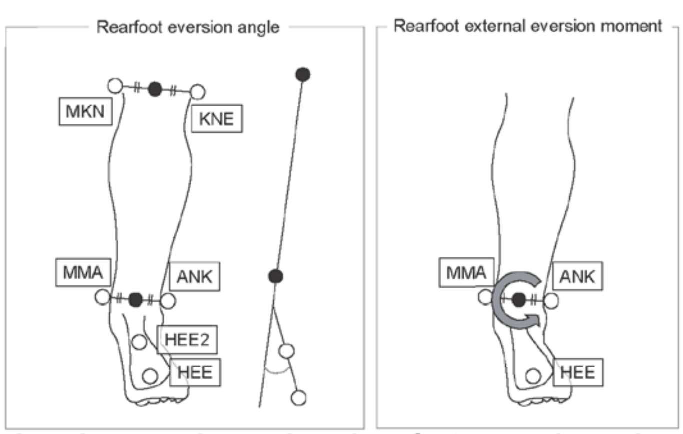

Figure 2: Illustrate of rearfoot eversion angle and rearfoot external eversion moment (back view of perpendicular to the longitudinal foot axis)

RESULTS: Figure 3 shows the average time series curves of the rearfoot eversion angle and rearfoot external eversion moment. The eversion motion was initiated from just after foot contact, then reached to maximum value in the first half of the stance phase. The external moment also exhibited from just after foot contact, then reached its maximum value at similar timing of the eversion angle in the first half of the stance phase. Correlation coefficient between the maximal eversion angle and the peak moment was very poor (r = -0.07, Figure 4).

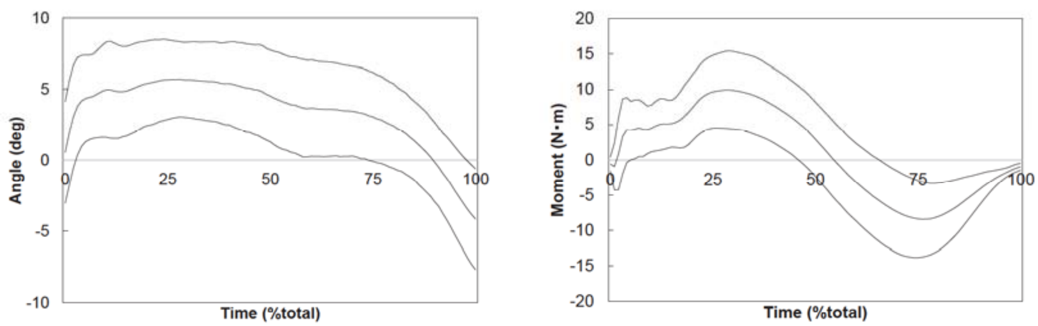

Figure 3: Average (± SD) curve of rearfoot eversion angle and rearfoot external eversion moment.

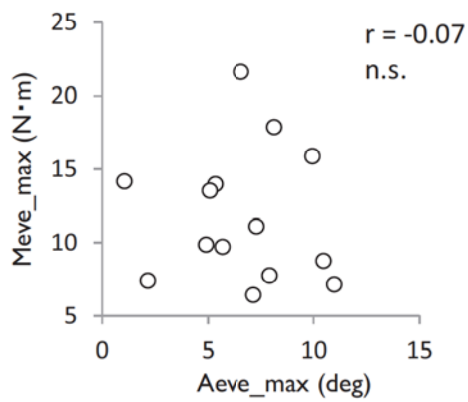

Figure 4: Relationship between maximun rearfoot eversion angle and maximum rearfoot external eversion moment.

DISCUSSION: To date, the majority of biomechanical researchers that focused on overuse running injuries, have explored kinematic variables such as rearfoot eversion angle. Despite the body of evidence accumulated for rearfoot eversion angle, the evidence has not been consistent (Messier and Pittala, 1988; Willems et al., 2006; Duffey et al., 2000; Ghani Zadeh Hesar et al., 2009; Noehren et al., 2013).
To address this issue, an attempt was made in the present study to clarify the relationship between the maximum rearfoot eversion angle and maximum rearfoot eversion moment which is thought to be a primary cause of overuse running injuries. It can be seen that the maximum eversion angle occurred simultaneously with the peak eversion moment in weight bearing, quasi static condition. That suggests that the eversion moment is most likely responsible for the change of eversion angle, however, there was no significant relationship (r = -0.07) between the magnitudes of the two variables. This result indicates that the external eversion moment is a main drive to cause rearfoot eversion motion whereas its magnitudes would not be estimated by the range of eversion motions due to the variety of joint stiffness and ROM among individuals. Therefore, it is not always true that runners who

showed equal eversion angle during running are suffering equal magnitude of external moment. Thus, it is not reasonable to use the rearfoot eversion angle as a substitute parameter of the external eversion moment. This is clear evidence that supports the suggestions made by Rodrigues et al. (2013). The result also may partially explain why the previous outcomes regarding the rearfoot eversion angle were inconsistent among studies. Dynamic analysis of the rearfoot external eversion moment is likely a better way to evaluate the susceptibility of overuse running injuries.

CONCLUSION: The rearfoot eversion angle during stance phase of running does not represent the magnitude of rearfoot external eversion moment.

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