Summary:
The purpose of this study is to measure the excursions and average moment arms of the all tendons across the first metatarsophalangeal joint. Eleven fresh frozen cadaveric lower extremities were used. Tendon excursions and moment arms of hallux tendons were measured. This study showed that all hallux tendons have mechanical advantages in moderate extended positions. The adductor hallucis muscle became especially the more effective in a more extended position of the metatarsophalangeal joint. The kinematic character of the adductor hallucis muscle is one of the causes of hallux valgus deformity, because high-heeled shoes enforce the first metatarsophalangeal joint extension.

Abstract:
Purpose:
Measurement and knowledge of the amplitude of excursion of each tendon of the hallux muscle have significant applications to studies of pathogenesis of hallux valgus, as well as to theoretical decision making for treatment. The hallux intrinsic muscles have never studied kinematically. The purpose of this study is to measure the excursions and average moment arms of the all tendons across the first metatarsophalangeal (MTP) joint during flexion-extension and to characterize changes in the instantaneous moment arms.

Methods:
Eleven fresh frozen cadaveric lower extremities (7 male 4 female, 62 to 89 years) were used. The extrinsic muscles (the extensor hallucis longus muscle (EHL) and the flexor hallucis longus muscle (FHL)) and the intrinsic muscles (the extensor hallucis brevis muscle (EHB), the abductor hallucis muscle (ABD), the oblique head (ADD-o) and the transverse head (ADD-t) of the adductor hallucis muscle, and the medial head (FHB-m) and the lateral head (FHB-l) of the flexor hallucis brevis muscle) were identified. Dacron braided suture lines were attached to the proximal ends of the cut tendons. The lines were routed through precision potentiometers to measure tendon excursions. A dual-axis electrogoniometer was mounted on the calcaneus and the great toe to monitor motion of the first MTP joint. The values of the first MTP angles were calibrated to an accuracy of 0.1 degree and tendon excursion values were rounded to 0.1 mm. The first MTP joint, guided by a metal bar, was moved through full flexion to full extension in the sagittal plane. Tendon excursions from 40 degrees flexion to 60 degrees of extension were used to analyze differences of excursions and moment arms between the tendons. An average of four measurements in each subject was used for the analysis. Instantaneous moment arm at a certain angle was calculated using excursions from the certain angle minus 5 degrees to plus 5 degrees. Differences of averages of excursions and moment arms between the tendons were analyzed by a two-way ANOVA.

Results:
Excursions of EHL, FHL, EHB, ABD, ADD-o, ADD-t, FHB-m and FHB-l were 17.5-4.9, 19.8-2.0, 13.9-2.3, 11.0-2.4, 12.2-3.5, 7.8-3.5, 14.0-3.3 and 14.3-2.3 (mean-SD, (mm)), respectively. Excursions of FHL and EHL were significantly larger than those of the intrinsic muscles. The averages of the moment arms were 10.0-2.8, 11.3-1.2, 7.9-1.3, 6.2-1.4, 7.0-2.0, 4.5-2.0, 8.2-1.3 and 8.0-1.9 (mean-SD, (mm)). Moment arms of all of the hallux tendons are the most effective in 10 to 30 degree extended position. The largest value of the instantaneous moment arm of each
tendon was observed at 15, 9, 16, 12, 34, 36, 16, and 15 degrees of extension, respectively. Especially, the values of ADD-o and ADD-t increased with extension of the MTP joint.

Conclusions:
All hallux tendons have mechanical advantages in moderate extended positions. The adductor hallucis muscle became especially the more effective in a more extended position of the metatarsophalangeal joint. The kinematic character of the adductor hallucis muscle is one of the causes of hallux valgus deformity, because high-heeled shoes enforce the first MTP joint extension.