Height and Flexibility of Foot Arch - Influence of Obesity -

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Disclosures:

Introduction:
Overweight may lead to mechanical trauma, degeneration, and eventually posterior tibial tendon dysfunction. Flexibility of the foot arch aids human gait by supporting the body weight against gravity. The tibialis posterior muscle is believed to be the most important dynamic support of the arch of the foot. However, no previous experimental studies have examined the influences of the obesity to the dynamic function of tibialis posterior tendon and flexibility of the medial longitudinal arch (FA). It is known that the flexibility of arch plays an important role in absorbing energy during gait. The aim of the present study was to investigate the FA which was calculated by the change of the medial longitudinal arch height (AH) during cyclic axial loading with obesity compared to the non-obese condition. We hypothesized that the AH and FA of the foot could not be maintained when the tibialis posterior tendon was overloaded.

Methods:
14 normal fresh frozen cadaveric legs were used. The mean age at the time of death was 82 years (range, 59 to 93). Each leg was cut at the proximal third of the crus. The proximal edge of each specimen was fixed with 2-mm Kirschner wires and mounted by 5-cm-diameter acrylic tube filled with polymethylmethacrylate resin. The leg was set at the neutral position on the custom jig. A total of 10,000 cyclic axial loadings of 500 N or 1,000 N (1Hz) were applied to the longitudinal axis of the tibia using the Materials Testing Machine (AG-1, SHIMADZU, Kyoto, Japan). The 32 N dynamic muscle loadings were applied to the tibialis posterior tendon. The experiments were divided into two groups. The 500 N cyclic axial loadings and 32 N dynamic muscle loadings were applied to the tibialis posterior tendon by the servomotor (normal group, n=7). The 1,000 N cyclic axial loadings and 32 N dynamic muscle loadings (obese group, n=7). A 1 mm² square red light emitting diode (LED) was attached to the medial aspect of the navicular with minimum disruption. The displacement of the LED light was monitored via a charge-coupled device (CCD) camera (Figure 1). (1) The image from the CCD camera was converted to the coordinate system. The translational accuracy was 0.06 mm (0.2% full scale). One cycle was determined that the period of over 5 N axial load applied. The navicular heights with initial 5 N axial load and a peak of axial load were recorded in each cycle. It means that the navicular height with minimum and maximum weight bearing, respectively. The arch change was evaluated using the bony arch index (BAI). (2) The BAI was determined by the navicular height to foot length ratio. A low arch was defined as a BAI with weight bearing of less than 0.21. The BAI with maximum weight bearing (BAI_max) and minimum weight bearing (BAI_min) were calculated for each 1,000 cycles. FA was defined as (BAI_min - BAI_max). Results were expressed as a mean ± standard deviation (SD). We compared BAI with maximum and minimum weight bearing and FA for each 1,000 cycles between normal and obese group by using a t test. A p value of 0.05 was chosen as the level of significance. This study was approved by our institutional review board (IRB).

Results:
The height of the navicular decreased with cyclic axial loading. The initial BAIs with maximum weight bearing were 0.242±0.011 (normal group), and 0.234±0.012 (obese group). The BAI of obese group decreased less than 0.21 after 1,000 cyclic axial loadings. On the other hand, the mean BAI of normal group were remained over 0.21. After 10,000 cyclic axial loadings, the mean BAIs with maximum weight bearing were 0.213±0.009 (normal group) and 0.180±0.023 (obese group). The initial BAIs with minimum weight bearing were 0.283±0.007 (normal group), and 0.276±0.018 (obese group). After 10,000 cyclic axial loadings, the mean BAIs with maximum weight bearing were 0.258±0.012 (normal group) and 0.197±0.025 (obese group). The initial value of FA were 0.045±0.011 (normal group) and 0.042±0.014 (obese group). After 10,000 cyclic axial loadings, FA were 0.046±0.013 (normal group) and 0.017±0.006 (obese group). Statistical significances were found between normal group and obese group in the mean BAI with maximum and minimum weight bearing after 1,000 cyclic axial loadings (Figure 2) and the FA after 2,000 cyclic axial loadings (Figure 3).

Discussion: We investigated the influence of the overweight to the arch height and flexibility during cyclic axial loadings with tibialis posterior muscle force. The present results showed that the BAI with obese group was significantly decreased after 1,000 axial cyclic loading and the flexibility of arch (FA) with obese group was significantly decreased after 2,000 axial cyclic loading. As maximum axial load is constant (1,000N), energy received by foot arch is proportional to flexibility (energy ∝ flexibility). Therefore, our results suggested that the decreased flexibility in the obese foot might diminish the energy absorbed at the foot
arch, and increase the load to the proximal weight bearing joints including ankle joint.

**Significance:** The decreased flexibility of arch in the obese foot might diminish the energy absorption, which could overload to the proximal weight bearing joint in their ADL. The prevention of obesity would be essential to keep arch flexibility of the obese foot.

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![Figure 1. Apparatus of experimental system](image)

![Figure 2. Bony arch index with maximal weightbearing](image)

* The BAI of obesity was significantly lower than normal (p < 0.05)
**Figure 3.** Bony arch index with minimal weightbearing

* The BAI of obesity was significantly lower than normal \( p < 0.05 \)

**Figure 4.** Flexibility of arch (FA, BAlmin-BAlmax)

* The FA of obesity was significantly lower than normal \( p < 0.05 \)

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