BIOMECHANICAL DIFFERENCES BETWEEN NEUTRALLY ALIGNED, PES CAVUS AND PES PLANUS FEET IN DIABETIC PATIENTS

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INTRODUCTION
Foot type is an architectural concept; feet may be broadly classified as one of three foot types: neutrally aligned, pes planus (low arch) and pes cavus (high arch). The neutrally aligned foot type is asymptomatic, healthy and well aligned. A pes planus foot type has little or no arch, while a pes cavus foot type has an abnormally high arch, both of which are primarily sagittal plane deformities.

Although peripheral vascular disease has been associated with ulceration, it is now understood that the majority of foot ulcers are caused by mechanical trauma to an insensate foot (Cavanagh et al. 2001). High plantar pressure, a measure of the mechanical trauma the tissue is exposed to, is often associated with abnormal foot biomechanics (Ahroni et al. 1999). However, the relationship between aberrant foot structure and altered plantar pressure distributions is not well documented. Nor has the concept of foot type been conclusively defined. Thus, in order to further our understanding of the ulceration process as it is related to foot architecture and aberrant plantar pressures, we must first increase our knowledge of the differences between foot types.

METHODS
The data employed for this study were previously collected for the Seattle Diabetic Foot Study (SDFS) (Boyko et al. 1999). Subjects were included if their foot type was determined as neutrally aligned, pes cavus (high arch) or pes planus (low arch). Subjects with current ulcers were excluded. Several biomechanical parameters were measured on each subject, including: 1) ankle, subtalar and first metatarsophalangeal joint mobility, 2) presence of foot deformity (muscle atrophy, bony prominences, as well as toe and metatarsal head deformities) and 3) various radiographic measurements. This study will report on the differences in the measured variables between foot types.

Chi-square tests were used to test for an association between foot type and categorical biomechanical measures. For continuous variables, a one way ANOVA was used to test whether means were different by foot type. Helmert contrasts were used to determine the pattern of significance among individual foot types.

RESULTS
There were several significant relationships between biomechanical measures and foot type (see Table 1). For hallucus dorsiflexion, pes cavus feet had increased motion and rigid pes planus had decreased motion. Pes cavus feet had lower hallucus plantar flexion. For the deformity measures, the percent of subjects with intrinsic muscle atrophy and bony prominences is significantly lower for the neutrally aligned feet, while the differences in the percent of subjects with hallucus valgus and hallucus limitus was higher with the rigid pes planus feet. Pes cavus feet had significantly higher percentages of bony prominences. Neutrally aligned feet had less hammer/claw toes, while occurrence of this malady was significantly greater for pes cavus feet. The pes cavus feet also had greater amounts of prominent metatarsal heads. Additionally, the neutrally aligned feet had a smaller percentage of plantar calluses. The X-ray parameters demonstrated longer metatarsal heads, greater intermetatarsal (IM) angles and lower lateral talometatarsal angle for both pes planus groups. Finally, the pes planus feet had significantly larger talocalcaneal angles.
neutrally aligned (n=1174) | pes cavus (n=493) | pes planus rigid (n=171) | pes planus flex (n=209) | p -value
--- | --- | --- | --- | ---
dorsiflexion | 8.1 ± 0.2 (760) | 7.4 ± 0.4 (349) | 9.0 ± 0.6 (107) | 8.3 ± 0.5 (151) | 0.063
calcaneal ever. | 15.1 ± 0.6 (117) | 17.5 ± 2.7 (28) | 15.9 ± 1.3 (21) | 15.4 ± 1.3 (34) | 0.6
calcaneous inv. | 18.2 ± 0.7 (117) | 18.1 ± 1.4 (28) | 18.7 ± 0.7 (21) | 17.8 ± 1.5 (34) | 1.0
hallux dorsi. | 38.8 ± 0.4 (806) | 44.6 ± 0.6 (372) | 36.0 ± 1.0 (118) | 39.1 ± 0.9 (168) | < 0.0001
hallux plan. | 33.8 ± 0.4 (804) | 27.8 ± 0.7 (370) | 32.8 ± 1.1 (118) | 32.1 ± 1.0 (168) | < 0.0001
int. mus. atrophy (%) | 49.0 (802) | 76.2 (370) | 71.1 (121) | 67.7 (164) | < 0.0001
bony prominences | 48.7 (799) | 78.1 (370) | 74.4 (121) | 65.7 (166) | < 0.0001
hallux valgus | 28.7 (1170) | 33.5 (490) | 43.8 (169) | 32.7 (208) | 0.0007
hallux limitus | 29.2 (1167) | 32.4 (491) | 42.3 (168) | 21.2 (208) | 0.0001
hammer/claw toes | 60.4 (1171) | 86.4 (491) | 74.7 (170) | 72.6 (208) | < 0.0001
prom. met. head | 53.4 (1169) | 86.2 (493) | 55.0 (171) | 64.1 (206) | < 0.0001
plantar callus | 52.0 (1173) | 59.6 (493) | 57.3 (171) | 57.9 (209) | 0.022
X-ray measures
| | | | | |
met. length (mm) | 4.01 ± 0.08 (455) | 4.10 ± 0.11 (221) | 4.64 ± 0.17 (86) | 4.76 ± 0.19 (91) | < 0.0001
inter. met. ang. (°) | 9.4 ± 0.1 (459) | 9.2 ± 0.2 (221) | 10.2 ± 0.4 (86) | 10.0 ± 0.3 (91) | 0.015
hal. valg. ang. (°) | 14.2 ± 0.3 (453) | 14.5 ± 0.4 (220) | 14.7 ± 1.0 (86) | 14.4 ± 0.8 (91) | 0.9
5th met. angle (°) | 11.5 ± 0.3 (455) | 11.2 ± 0.5 (220) | 11.9 ± 0.8 (86) | 10.5 ± 0.6 (91) | 0.6
lat. ta-calc. ang. (°) | 45.8 ± 0.4 (459) | 47.8 ± 0.4 (221) | 44.4 ± 0.8 (86) | 44.7 ± 0.7 (91) | < 0.0001
lat. ta-met. ang. (°) | 0.0 ± 0.5 (458) | -1.7 ± 0.6 (221) | 9.8 ± 1.3 (86) | 5.6 ± 1.0 (91) | < 0.0001

Table 1: The differences between foot types for several biomechanical parameters.

**DISCUSSION**

A prospective study of the differences of several biomechanical parameters between neutrally aligned, pes cavus and pes planus feet was conducted. The data indicated that there were several interesting differences between the foot types. Pes cavus feet have abnormal first metatarsophalangeal joint ranges of motion (both in dorsiflexion and plantar flexion) as well as increased percentages of hammer/claw toes and prominent metatarsal heads. These findings are all indicative of aberrant metatarsophalangeal joint mechanics found with pes cavus feet (Green *et al.* 1987). Neutrally aligned feet have lower percentages of intrinsic muscle atrophy, bony prominences, hammer/claw toes and plantar calluses, all of which is consistent with neutrally aligned feet being asymptomatic. Additionally, rigid pes planus feet had higher percentages of hallux valgus and hallux limitus, a finding contradicted in the literature (Kilmartin and Wallace 1992), perhaps because that study dealt with children and did not differentiate between rigid and flexible feet. Finally, both rigid and flexible pes planus feet demonstrated differences in X-ray parameters that have been observed previously (Gould 1982). This study provides a further understanding of the relationship between foot structure and foot function in a large scale, prospective manner.

**ACKNOWLEDGEMENT**

This work was funded by The Seattle Epidemiologic Research and Information Center.

**REFERENCES**


