Electrical stimulation of the abductor hallucis helps counteract the deformation of foot arches

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Summary

This study examined how foot load and electrical stimulation of the abductor hallucis (ABH) affect the morphology of foot arches. Results indicated that increasing foot load flattened the arch, while the ABH electrical stimulation was effective in counteracting the deformation of the medial longitudinal arch and transverse arch.

Introduction

The morphology of foot arches is related to its weightbearing function and foot stability[1]. However, compare to the medial longitudinal arch (MLA), few studies have focused on the transverse arch (TA), which provides over 40% of foot stiffness[2]. The ABH functions to support the first ray, and thus increasing its activation (via electrical stimulation) may also affect the morphology of the TA. The study aimed at investigating the effects of foot load and the ABH electrical stimulation on arch morphology.

Methods

Eight young adults were recruited in the study (age: 22.4±1.7 years; height: 166.8±5.8 cm; weight: 57.3±10.5 kg; male: female = 4:4). The experiment protocols were: 1) static test without electrical stimulation: sitting (SIT), double-leg standing (DLS), and single-leg standing (SLS); 2) static test with ABH electrical stimulation (maximum tolerable stimulus intensity, 100 Hz, width pulse: 1 ms). Markers were placed on the proximal and distal ends of five metatarsals, the distal medial side of the first metatarsal, and the heel to assess foot arch morphology. Differences were assessed using one-way repeated measures ANOVA with Bonferroni correction if the data was normal distribution.

Results and Discussion

As foot load increased from SIT to SLS, the transverse arch fitting circle radius (TAR) increased significantly (p=0.008, Figure 1a), suggesting that increasing foot load flattened the TA. This alteration was largely attributed to the deformation on the 1st and 2nd ray, as notable differences in metatarsal angle were observed only in the 1st and 2nd metatarsals (p<0.01 and p<0.05, Figure 1b).

The ABH electrical stimulation resulted in 1.0% and 0.6% reduction in the MLA length during SIT and DLS (p=0.002 and p=0.01, Table 1), while the TAR significantly decreased by 1.1% during DLS (p=0.038), indicating that electrical stimulation induced ABH contraction to attenuate the MLA and TA deformation. The MLA may be more susceptible to ABH electrical stimulation for its elasticity[2] and the course parallel to the ABH. We did not observe significant changes in SLS. This may be due to the high activation of ABH in SLS, resulting in that electrical stimulation could not induce further ABH activation to modify the arch morphology in SLS.

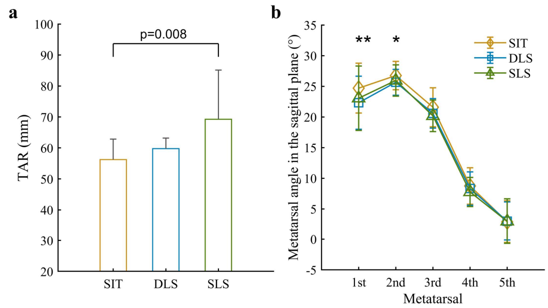

Figure 1: Foot arch morphology in three static postures: a) metatarsal angle in the sagittal plane; b) transverse arch fitting circle radius (TAR) in the frontal plane; SIT: sitting; DLS: double-leg standing; SLS, single-leg standing; *DLS vs SIT p<0.05; ** DLS vs SIT p<0.01.

Table 1: The effect of ABH electrical stimulation on arch deformation.

Postures	Variables (mm)	non-ES	ES	*p*-value
SIT	MLA length	200.55±7.35	198.56±7.33	**0.002****
	TAR	55.82±8.47	55.38±8.01	0.21
DLS	MLA length	204.87±8.49	203.45±8.40	**0.01***
	TAR	60.23±4.05	59.58±3.92	**0.038***
SLS	MLA length	204.84±9.47	204.36±9.22	0.14
	TAR	61.98±8.67	62.19±8.93	0.21

SIT: sitting; DLS: double-leg standing; SLS, single-leg standing; MLA, medial longitudinal arch; TAR, transverse arch fitting circle radius in the frontal plane; ES, electrical stimulation; **p<0.01; *p<0.05.

Conclusions

The MLA and TA morphologies deform in response to foot load, probably due to the deformation of the 1st and 2nd rays. Electrical stimulation of the ABH has an effect on counteracting the deformation of the MLA and TA in low foot load situations.

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References

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