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Arch-spring or windlass mechanism? The stiffness of sprinters’ and swimmers’ feet: A pilot study

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INTRODUCTION:
The human foot is thought to function like a flexible spring (Ker 1987) or a stiff lever (Hicks 1954). In both mechanisms, the stiffness of the plantar aponeurosis (PA) plays a central role in the deformation of the longitudinal arch (LA) under loading. If the PA is sufficiently stiff, metatarsophalangeal joint (MPJ) dorsiflexion should be closely coupled to LA deformation. We assume that, due to their daily impact load, sprinters have stiffer LA than swimmers. Therefore, more force might be needed for MPJ dorsiflexion, which should lead to greater deformation of the LA of sprinters compared to swimmers.
METHODS:
Force-deformation of the MPJ during passive dorsiflexion was determined with a custom-built device in five male competitive sprinters (100 m PB 11.57 ± 0.46 s, training/week 10.8 ± 1.1 hrs) and eight male competitive swimmers (50 m freestyle PB 24.8 ± 1.18 s, training/week 12.5 ± 3.3 hrs). Deformation of the LA (change in navicular angle) was recorded with a motion analysis system (Vicon, Oxford). For statistics a Mann-Whitney-U-Test (SPSS Statistics 23, IBM) with a level of significance $\alpha < 0.05$ was used.
RESULTS:
Forces for MPJ dorsiflexion were sig. ($p < 0.05$) higher in sprinters than in swimmers throughout the whole range of motion. At 40° MPJ dorsiflexion, the stiffness was 1.6 times higher in sprinters ($p < 0.05$). Energy absorption and return were 1.7 times elevated in sprinters compared to swimmers. Energy loss for the sprinters’ feet was 28% and for the swimmers’ feet 35%. The deformation of the LA increased by about 5° with increasing MPJ dorsiflexion, but showed no sig. differences ($p > 0.05$) between groups.
CONCLUSION:
Our results showed that the forces for MPJ dorsiflexion noticeably deformed the LA (Carlson et al. 2000). The relationship between MPJ angle and LA deformation aligned well with the windlass mechanism and was observed for both groups. The higher force requirement to induce a similar LA deformation in sprinters might be explained by the difference in tissue material properties between the groups (Arampatzis et al. 2007). It is possible that the stiffer LA of the sprinters was a result of the higher impact load per training week. Their stiffer tissue was able to absorb and return more energy with a smaller hysteresis. Sprinters might benefit from their stiff arch-spanning structures that inhibit LA deformation and allow an efficient force transfer rapidly to the ground during running. As a stiff foot is a requirement for efficient ground contact, specific long-term training interventions may be developed and monitored using this device. Further, the interaction with muscular factors (strength and activation) may be included in the scope of study.
REFERENCES:
1) Ker et al., Nature, 1987;
2) Hicks, J Anat, 1954;
3) Carlson et al., Foot & Ankle Int, 2000;
4) Arampatzis et al., J Biomech, 2007 .

Topic: **Biomechanics**

Presentation **Poster**