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Effects of increased toe flexor muscle strength to foot and ankle function in walking, running and jumping

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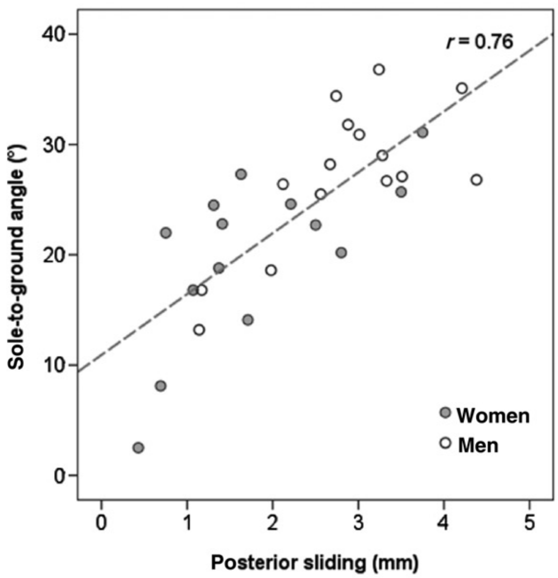

Figure 1. Influence of the sagittal plane sole-to-ground angle at initial foot contact on the sliding of the rearfoot element in posterior direction.

Comparison of genders showed that the posterior sliding of the element was increased in men (2.8 ± 0.9 mm vs. 1.8 ± 0.8 mm; $p = 0.01$) while there was no difference in the lateral displacement between the two groups. With respect to the explanatory factors of the regression model men had significantly increased sagittal plane sole-to-ground angles at touchdown compared to female runners ($27.2 \pm 6.7°$ vs. $20.0 \pm 7.3°$; $p = 0.01$).

Discussion and conclusion

The function of the rearfoot element is triggered by the foot-to-ground position at touchdown and by the initial loading rate characteristic of the ground reaction force. The distinct differences between men and women in sole-to-ground angle at touchdown explain why the function of the shoe is different between genders.

Consequently, based on the results of this study structural gender tailored modifications of rearfoot technologies in running shoes can be derived.

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Introduction

Driven by experience and intuition, barefoot training is commonly used by athletes to increase foot muscle strength, to prevent injury and to enhance performance. With the aim to simulate barefoot conditions, the production of sport shoes with flexible midsole constructions grew up in the last few years. It could be shown that flexible footwear allows higher ranges of dorsiflexion in the metatarsophalangeal joint (MPJ) than conventional footwear (Goldmann *et al.* 2010). The effects of wearing flexible shoes over five month determined Brüggemann *et al.* (2005) and identified an increase of toe flexor strength (TFS) of nearly 20%. However, the outcome on gait patterns and sports performance remained mostly unclear. Currently it is discussed whether muscle strength training alters dynamic joint loading or not (Thorstensson *et al.* 2007, Thorp *et al.* 2010).

Purpose of the study

Therefore, the purpose of this study was to evaluate the effects of increased TFS to foot and ankle function in walking, running and jumping.

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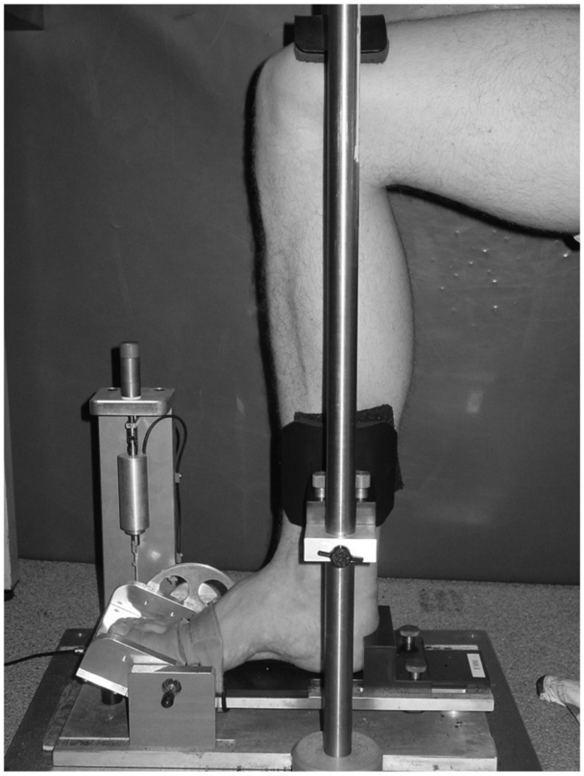

Figure 1. Custom-made dynamometer designed to determine MPJ moments.

Methods

Twenty three men participated in this prospective longitudinal designed study and were randomly divided in two groups: The experimental group (EG, $n = 14$; 24 ± 4 years, 77 ± 9 kg) performed a heavy resistance TFS training with 90% of the maximal voluntary isometric contraction (MVIC) for 7 weeks, 4 days per week, four sets per session (five repetitions, 3 s loading, 3 s relaxation) for the left and right foot. The control group (CG, $n = 9$; 25 ± 3 years, 76 ± 6 kg) participated in no training programme and continued their daily activities. The software controlled training programme was performed in a custom made dynamometer (Figure 1). Max. MPJ plantar flexion moment (M_{MPJ}) and max. ankle plantar flexion moment (M_{ankle}) during a MVIC were measured before (PRE) and after (POST) the intervention. To evaluate the training effects on foot and ankle function PRE and POST, motion analysis (inverse dynamics) were performed during barefoot walking ($1.6\,\mathrm{m\,s^{-1}}$), running ($3.5\,\mathrm{m\,s^{-1}}$), vertical and horizontal jumping (as high/far as possible).

Results

Between PRE and POST M_{MPJ}, M_{ankle} and jumping length increased significantly ($p \leq 0.05$) in the EG. In the standing long jump the max. MPJ moment was significantly ($p \leq 0.05$) higher and the MPJ absorbed 12% and the ankle generated 6% more energy. There were no differences ($p \geq 0.05$) in all parameters of walking, running and vertical jumping in the EG and CG between PRE and POST.

Discussion and conclusion

Toe flexor muscles highly respond to increased loading within few weeks. The increased force potential could not alter gait patterns but influenced standing long jump performance. In this jumping task, MPJ and ankle are dorsiflexed and high moments of force appear. The toe flexor muscles may operate at the plateau region of the force–length relation in these dorsiflexed joint angles (Goldmann *et al.* 2011). Furthermore, enlargement of the functional base of support (anterior shift of the center of force application under the distal phalanx) may influence the center of mass take off angle in the standing long jump. This could be a further reason for higher MPJ moments and increased jumping length (Endo *et al.* 2002, Wakai 2005). It could be shown that TFS training has an effect on sports performance.

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