THE CHOICE OF TRAINING FOOTWEAR HAS AN EFFECT ON CHANGES IN MORPHOLOGY AND FUNCTION OF FOOT AND SHANK MUSCLES

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The use of minimal footwear leads to higher muscle activity of the M. flexor hallucis longus and to a higher range of motion in the metatarsophalangeal joints (MPJ). This could lead to training effects of in- and extrinsic foot structures as muscles and tendons. The purpose of the study was to determine whether muscle strength or the anatomical cross sectional area of foot and shank muscles are affected by the use of minimal footwear. In a longitudinal prospective intervention study the effect of the use of a minimal shoe was evaluated. Therefore isometric MPJ flexion strength, inversion strength and plantar flexion strength were determined. The effect on the anatomical cross sectional areas (ACSA) of selected foot and shank muscles were measured using MRI. ACSA as well as muscular performance increased significantly using the minimal shoe in comparison to conventional footwear. This should lead to performance enhancement and injury prevention.

KEY WORDS: footwear, adaptation adaptation, in- and extrinsic foot muscles, M. flexor hallucis longus (FHL), strength, ACSA

INTRODUCTION: As biological structures receive mechanical stimuli they are getting stronger. If muscles, tendons and bones are not in use they will decrease strength and their functional capacity. The biological structures of the foot can be trained by barefoot walking or workout through the speculated higher loading. No scientific evidence for a causal relationship between increased foot loading and functional improvement of foot structures could be found in the literature. The foot arch and the foot functional capacity are strongly related to the strength of the flexor muscles of the metatarsophalangeal joints (MPJ): M. flexor hallucis longus (FHL) and M. flexor digitorum longus (FDL) (Jacob, 2001; Kitaoka, 1994; Tochigi, 2003). In pilot studies it was shown that a special designed minimal shoe (Nike FREE) increases the range of motion (ROM) on the metatarsophalangeal joints (MPJ) and the ankle joint in normal walking. It also modifies the plantar pressure distribution. Using the minimal footwear both the ROM as well as the plantar pressure distribution was similar to those patterns found in barefoot walking on grass. In a second pilot study using wire EMG technique the muscle activity of the FHL was shown to be substantially increased during walking in the minimal footwear in comparison to walking in traditional running shoes. If training with the minimal footwear mimics barefoot training one can assume that using the minimal shoe the loading of the foot structures will increase and the structures – especially the muscles – will become stronger.

The purpose of this study was to demonstrate the capacity of biological structures to adapt to mechanical stimuli modified through footwear and to quantify effects on strength and morphology of the foot and shank muscles. The research question was to quantify the impact of increased mechanical stimuli on (1) muscle strength and (2) anatomical cross sectional area (ACSA) of intrinsic foot and shank muscles.

METHODS: The research question was solved by a prospective longitudinal designed approach. The prospective study operated with an experimental (EXP; $n_{EXP} = 25$) and a control group (CTR; $n_{CTR} = 25$) both consisting of healthy and physically active male and female subjects. The experimental intervention for the subjects of EXP over a period of five months was the use of the minimal footwear in the preparatory (warm up) training while the control group used traditional training shoes for the same training program. Both groups had to record all sport activities including the specific tasks in a training diary and the subjects of EXP in addition all other wearing hours of the experimental shoe. The minimal shoe had a very thin upper material without a heel counter and a mid- and outsole segmented into 27

segments by deep flex grooves (Figure 1).
To evaluate the training effect on foot and shank muscles the muscular performance was measured in a pre test (PRE) before the intervention period and in a post test (POS) five months later. Those measurements of muscle strength were performed using special custom built dynamometers. During maximal voluntary isometric contractions the MPJ flexor strength, inversion moment, plantar flexor strength and inversion moment were determined. Special care was taken to ensure that knee and ankle angles were kept at 90° in both PRE Plantar fl. strength as well as POS.
To evaluate an effect on the morphology of the foot muscles ACSA of FHL, FDL, M. triceps surae (TS), Mm. tib. post (TP) and ant.(TA), M. peroneus (PER) at the greatest diameter of the shank and ACSA of four of the intrinsic foot muscles (M. abductor hallucis, M. quadratus plantae, M. abductor digiti minimi, M. flexor digitorum brevis) were estimated by MRI (Siemens Symphony, 1.5 Tesla).

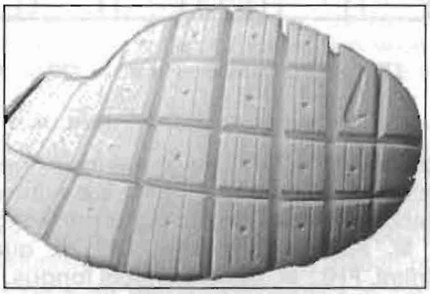

Figure 1 Outsole in the forefoot area of the experimental shoe. Note the deep flex grooves in the outsole.

RESULTS: The muscle strength changes through the intervention showed a significant ($p<.01$) increase of the MPJ flexors in EXP; no significant change in CTR. Plantar flexion strength increased only significantly ($p < .05$) in the experimental group. The maximum supinator muscles torque increased for the experimental group ($p < .05$) and showed no effect on the control group (Table 1).

Table 1: Mean values and standard errors of MPJ flexor strength [N], subtalar inversion strength [Nm], plantar and flexors strengths [N]. Significant differences between PRE and POS are indicated with * $p < .05$ and ** $p < .01$.

	Experimental group		Control group	
	PRE	POS	PRE	POS
MPJ flexor strength	232 (10.9)	279 (11.6) **	228 (11.1)	237 (11.6) ns
Inversion moment	18.0 (1.4)	21.8 (1.6) *	17.5 (1.3)	17.7(1.2) ns
Plantar fl. strength	1065 (72.2)	1254 (73.2) *	1296 (68.0)	1242 (63.1) ns

While for the Mm tibialis anterior, peronei, tibialis posterior and triceps surae no substential changes in the ACSA were found, the ACSA of the FDB, AH, QP, ADM and FHL increased between 4% and almost 10% (Figure 2).

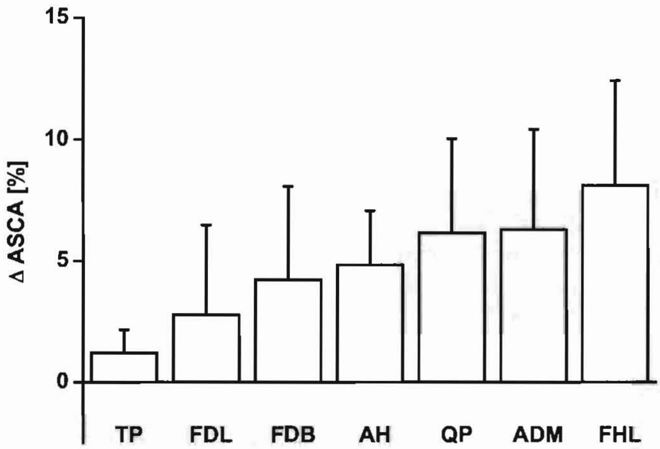

Figure 2 Relative increase of ACSA of six extrinsic foot muscle through the five months intervention (Mean and SEM); experimental group (n_E = 25). TP: M. tibialis posterior, FDL: M. flexor digitorum longus, FDB: flexor digitorum brevis, AH: M. abductor hallucis, QP: M. quadratus plantae, ADM: M. abductor minimi, FHL: M. flexor hallucis longus.

DISCUSSION: The presented five month longitudinal study showed a significant effect of the intervention through minimal footwear on muscular performance regarding MPJ flexion, subtalar inversion and plantar flexion. An effect on morphology for intrinsic and extrinsic foot muscles could also be shown. This effect was greatest in FHL, ADM and QP. All muscles showing a substantial increase in ASCA have an effect on toe flexion and are responsible for maintaining the longitudinal arch of the foot. The increase in plantar flexion strength and inversion moment of EXP can be explained by the function of FHL and FDL as plantar flexors and inverters. Apparently the use of the experimental footwear loads the affected lower leg and foot muscles in a way that bio positive adaptations are initiated. It can be assumed, that the special design of the shoe is the reason for that effect.

CONCLUSIONS: The use of the minimal shoe under study leads to an increase in muscle performance of in- and extrinsic foot muscles. Therefore it can be concluded, that training in minimal footwear induces mechanical stimuli leading to biopositive adaptations. It should be an effective approach for injury prevention and performance enhancement to use minimal footwear in well defined training regimes.

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