CHANGES IN MORPHOLOGY AND FUNCTION OF TOE FLEXOR MUSCLES ARE RELATED TO TRAINING FOOTWEAR

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INTRODUCTION

Without scientific proof but driven by experience and intuition barefoot training is commonly used by coaches and athletes for both injury prevention and performance enhancement (Pinnington 2001). Due to geographic and climatic circumstances not everywhere in the world it is practically possible to train barefoot, e.g. outdoors on grass, the whole year through. Therefore it can be hypothized that an especially designed training shoe with a multiple segmented outsole, mimicking barefoot movements and allowing barefoot-like exercises on hard surfaces, could induce different mechanical stimuli on foot and shank muscles. A biopositive adaptation should be advantageous in terms of injury prevention or performance enhancement. The purpose of this study was to identify an eventual training and adaptation effect in morphology and function on foot and lower leg muscles when wearing such a specifically designed training shoe.

METHODS

Study Design

One hundred physically active healthy subjects (23.3±3.8years; 1.77±0.01m; 69.5±11.6kg; 48 female; 52 male) were randomly assigned into an experimental group (EXP, n_{EXP}=50) and a control group (CTR, n_{CTR}=50). At the beginning of the test period every subject had to undergo a pre-test (PRE) with biomechanical measurements regarding isometric muscle strength and movement analysis. The pre-test was followed by the group specific intervention. To control the after the intervention a post-test (POS) including the same measurements as PRE was performed.

Intervention

Both groups had to perform specific exercises for 20 to 30min four times a week (running, aerobics, moderate side steps, skipping…). They could be performed during the warm up in sport classes and sport clubs or could be performed individually. During the exercises the subjects of CTR wore their conventional footwear. The subjects of EXP wore a specifically designed training shoe (Nike Free). This 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). In pilot studies it was identified, that this shoe allows movements of the foot - especially in the toe area – similar to those observed in barefoot running and walking (Pisciotta 2004). The experimental group was allowed to wear the shoe during the specified activities as well as during every day live. Both groups had to record all sport activities including the specific tasks in a training diary and the subjects of EXP in addition all wearing hours of the experimental shoe.

Biomechanical Testing

To evaluate the training effect on foot and shank muscles the toe flexor strength (TFS), the passive range of motion (ROM) of the first metatarsophalangeal joint (MPJ) and its active path of motion (POM) during walking was measured. For 25 randomly chosen subjects of EXP the muscle volumes of the flexor hallucis longus, abductor hallucis, tibialis posterior and flexor digitorum longus were calculated.

For TFS measuring a custom made dynamometer based on piezo transducers (Kistler®, 1000Hz) was used. Knee and ankle angle were constant at 90°. The maximum force of three maximal voluntary isometric contractions was taken. To examine the ROM of the MPJ an electronic custom made goniometer was used measuring the maximal dorsiflexion angle of the MPJ. During walking at 1.8±0.2m/s the movement of the foot during stance in the sagittal plane was recorded (125Hz). With a two-segment model the maximal change of the MPJ angle was calculated to examine POM. Magnetic resonance images were taken from the lower leg (sagittal plane) and foot (frontal) of 25 subjects of EXP. To determine morphological changes of selected lower leg muscles the volumes from 1.45cm above to 1.45cm below the greatest diameter were calculated (3D-Doctor 3.5®). For the selected foot muscles the volumes were calculated from 4mm before and 4mm behind the greatest muscle diameter.

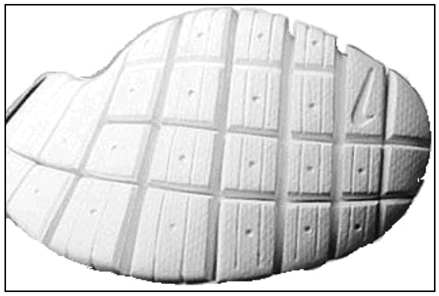

Figure 1: Outsole in the forefoot area of the experimental shoe. Note the deep flex grooves in the outsole.

To identify differences in the dependent variables between EXP and CTR T-Tests for independent samples and between PRE and POS T-Tests for paired samples were performed ($p \leq 0.05$; SPSS for Windows®).

RESULTS

The subjects of the control group showed no significant change in the flexor strength between PRE and POS. The subjects of the experimental group however showed significant differences in TFS between PRE and POS ($p<0.01$). In the EXP group TFS increased by 47N (20%).

The mean POM of the MPJ was 46°±9 dorsifexion over all subjects. In CTR the POM changed not significantly from PRE to POS (mean: 0.8°, $p=0.6$). In EXP the POM decreased significantly by a mean angle of 3° (7%) from PRE to POS ($p=0.018$).

The muscle volume of the 25 randomly chosen subjects for the magnetic resonance images of EXP showed a significant increase in muscle volume of about 5% for the flexor hallucis longus ($p \leq 0.05$). For the abductor hallucis ($p=0.08$) and the tibialis posterior ($p=0.07$) increasing trends by 4 to 5% could be identified. No significant changes for the flexor digitorum longus ($p=0.3$) and other lower leg muscles were found.

No significant changes in the passive ROM of the MPJ were found in EXP or CTR respectively.

DISCUSSION

The presented six month longitudinal study showed a significant effect of the intervention through footwear in toe flexor strength, active POM of the MPJ during walking and muscle morphology for selected muscles. Since EXP showed an increase in TFS as well as a decreased POM it can be assumed that the higher maximal force of the toe flexor muscles leads to a reduced dorsiflexion in the MPJ during gate. 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. The adaptation effect through the shoe is supported by the increase in muscle volume. If muscle strength can prevent from injuries (Fredericson 1996) or stiffening of the MPJ can enhance performance (Stefanyshyn 1997) the increased training effect of the toe flexor muscles through the experimental footwear should be advantageous.

ACKNOWLEDGMENTS

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