Effects of medial longitudinal arch supports on three-dimensional foot motion in high and low arched healthy adolescents
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Introduction: Orthotic insoles are used in conservative treatment of foot pain and foot related impairments in many patient groups [1] to alter foot loading and foot motion parameters [2]. Insoles with medial postings were suggested to reduce the evasion of the rearfoot but the effects were often non-systematic and subject-specific [2]. Furthermore, intrinsic and extrinsic factors like foot type and neuromuscular mechanisms seem to influence the effects of orthotic insoles [3]. However, there is a lack of evidence concerning the effects of orthotic insoles on foot loading and foot motion which makes it difficult to propose general guidelines for prescription [4,5].

Recent foot models allow a more detailed investigation of foot motion [6,7] and therefore could lead to a deeper understanding of orthotic effects on foot motion. Therefore, the aim of this study was to investigate the immediate effects of orthotic insoles in healthy subjects with high and low arch foot type using a new foot model.

Materials and Methods: Subject groups:
Eighteen otherwise healthy subjects were recruited when they conformed to either one of the desired foot types (Table 1). The following exclusion criteria applied: injuries of the lower extremity within the last six months, a history of foot surgery, systemic diseases like diabetes or rheumatoid arthritis and neurological disorders.

Tab. 1: Anthropometric data of the two subject groups

| Age (years) | 22.4 ± 1.2 | 22.8 ± 1.3 | n.s. |
| Height (m) | 173 ± 0.1 | 174 ± 0.1 | n.s. |
| Weight (kg) | 72.2 ± 1.4 | 68.1 ± 1.5 | n.s. |
| BMI (kg/m²) | 22.5 ± 1.0 | 21.1 ± 1.1 | n.s. |
| Arch Index | 0.17 ± 0.02 | 0.11 ± 0.03 | < 0.001 |

Orthotic Insoles:
Two orthotic insoles were used in this study. The first type included a medial longitudinal arch support with the highest elevation under the midfoot. The second type contained a support for the medial rearfoot with the highest elevation beneath the sustentaculum tali. Both insoles were worn in a sandal that was custom-built for this study to allow for marker placement for motion analysis.

Motion Analysis / Foot Model:
The foot model consists of four segments: shank, rearfoot and forefoot, that was further subdivided in the first ray and the lateral forefoot. Thus, the motion of the first ray in relation to the lateral forefoot and the rearfoot could be analyzed. Foot and shank motion was captured and analyzed by a 5-camera Motion Analysis system (Santa Rosa, CA, USA). Five measurements of the right foot were conducted during walking at self-selected speed for the following conditions: barefoot, sandal without insoles, sandal with insole type 1 and type 2.

Pedobarography:
Pedobarographic measurements were conducted simultaneously with motion analysis with a capacitive platform (EMED ST4, Novel GmbH, Munich, Germany) to detect the arch index of the subjects (Table 1).

Statistics:
A repeated measures ANOVA was used to reveal significant differences between the four conditions as well as for the two foot types (StatView 5.0, SAS Institute, Cary, NJ). Scheffé-test served as a post-hoc test. The significance level was set at p < 0.05.

Results: Accuracy of Measurements:
The results showed high intra-individual reproducibility and reliability for all foot motion parameters. Nevertheless, a high inter-individual variability between the subjects could be seen.

Group Differences:
The results revealed only few significant differences between the low and the high arched subjects. Dorsiflexion was significantly higher in the high arched group during the stance phase. Furthermore, the high arched subjects showed a significantly lower rearfoot eversion than the low arched subjects. The flattening of the medial longitudinal arch was more pronounced in the low arched group during stance phase.

Insole Differences:
Significant differences between barefoot and the shod conditions could be seen in sagittal, frontal and transversal plane motion. Wearing the sandal with or without insoles significantly reduced the range of motion (ROM) in almost every motion: Dorsiflexion of the rearfoot in the talocrural joint as well as dorsiflexion, eversion and abduction of the forefoot in relation to the rearfoot decreased significantly while wearing the sandal. Furthermore, the adduction of the first ray in relation to the lateral forefoot and the forefoot spreading is significantly greater while walking barefoot in comparison to the remaining conditions.

The two insoles caused a further reduction of ROM in comparison to the condition in sandals without insoles. Eversion of the rearfoot and flattening of the medial longitudinal arch were significantly reduced with both insoles during loading response and late stance respectively. No significant differences could be seen between both types of insoles.

Discussion: The foot model proved valid for capturing and representing foot motion during walking. The range of motion of the evaluated parameters are in accordance with established foot models [6,7]. High reproducibility and reliability indicate consistent values in repeated measurements. Pronounced variability between subjects suggests subject-specific responses to the interventions [2].

The group differences are in accordance with other studies [8]. A more pronounced dorsiflexion during mid-stance in the high arched subjects seems to be necessary to counter-act the reduced flexibility in the midfoot that was revealed in a reduced flattening of the medial longitudinal arch in comparison with the low arched subjects. During push-off the more rigid midfoot of the high arched subjects caused a reduced plantarflexion in the talocrural joint.

The differences between the four conditions were less pronounced and therefore the results have to be interpreted cautiously. There was agreement and discrepancy to results from other studies. Increased evasion of the rearfoot in sandal conditions was in accordance with results from other studies [2,9] whereas a reduction of tibial internal rotation could not be seen. No differences between the two insole conditions could be due to using standardized orthotic insoles. Custom made insoles might have revealed significant differences and should be used in further studies.

In conclusion the foot model proved to be a useful tool for describing and analyzing foot motion during walking. There are significant differences in foot motion due to foot type and orthotic insoles but the individual responses of the subjects to the interventions do not allow generalized conclusions.

References: