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CHANGES IN KNEE ADDUCTION MOMENT AND KNEE JOINT ALIGNMENT IN THE FRONTAL PLANE BY AN ANKLE-FOOT-ORTHOSIS

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SUMMARY
The aim of this study was to analyze the effect of an ankle-foot-orthosis (AFO) on the knee adduction moment as an alternative conservative treatment for medial knee osteoarthritis. Subjects with knee varus alignment were analyzed in five different conditions: without orthotic, with laterally wedged insoles and with an AFO in three different adjustments. Kinetic and kinematic data were collected using 3D gait analysis. Significant decreases in the knee adduction moment, knee lever arm and knee joint angle in the frontal plane were observed with the AFO, indicating load reduction in the medial knee compartment.

INTRODUCTION
Osteoarthritis (OA) is a frequent cause of disability in the elderly population. Medial knee OA progression was reported in patients with higher knee adduction moment (KAM), which is an indicator of load distribution between medial and lateral knee compartments [1].

The use of orthotic devices as conservative therapy for knee OA should contribute in reducing the mechanical load in the affected knee compartment. Valgus knee braces and lateral wedged insoles have been shown to be effective in reducing the KAM to different extents [2]. An alternative for decreasing the KAM could be achieved by increasing the ankle joint stabilization using an ankle-foot orthosis (AFO), which should keep the tibia in a more vertical position, thereby reducing the knee varus deformity. This vertical tibia position would lead to a more medial location of the knee joint center, reducing the knee lever arm in the frontal plane and therefore causing a decrease of the KAM.

The purpose of this study was to analyze the effect of an AFO in different adjustments on knee joint kinetics and kinematics.

METHODS
Fourteen healthy male subjects with varus knee alignment participated in this study (age: 24 ± 4.8 yrs, height: 178.8 ± 5.7 m, mass: 73.7 ± 8.0 kg). Each subject performed walking trials in each of the following conditions in a random order: without any kind of orthosis (baseline); with laterally wedged insoles (4º inclination); AFO in neutral; in 4° valgus and in 4° varus adjustments. Participants underwent 3D gait analysis using a 10 infrared camera system (VICON Motion Systems) at 200 Hz and two force plates (Kistler Instruments) at 1000 Hz. The moments acting about each joint were calculated by an inverse dynamic model and expressed as external moments.

A prototype of an ankle-foot-orthosis (AFO), which was developed to induce changes in the tibia position in the frontal plane and stabilize the ankle joint, was used in this study. This prototype comprised a sole, which was inserted in the shoe, and a unilateral tubular frame, which passed laterally upwards along the shank and was connected to the subject's leg via a fastening device with straps (Figure 1a). The orthosis joint could be adjusted in several varus/ valgus angulations, which should lead to changes of the tibia position in the frontal plane. The "valgus adjustment" was defined as the adjustment which would induce a more valgus alignment at the knee, by avoiding a lateral shift of the proximal aspect of the tibia (Figure 1b).

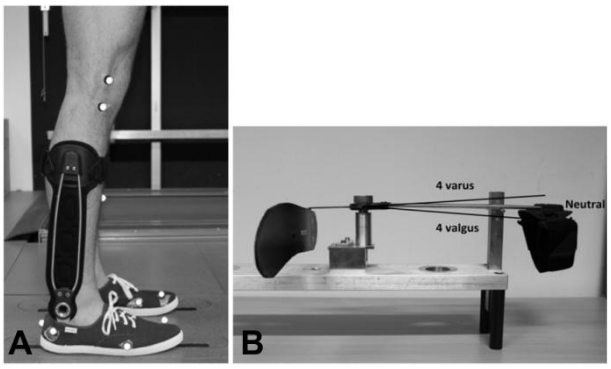

Figure 1: a) Subject wearing the AFO; b) Orthosis adjustments.

Variables of interest were knee adduction moment (KAM), knee lever arm in the frontal plane, position of knee joint center, position of center of pressure (COP), inclination and magnitude of the ground reaction force vector (GRF) in the frontal plane.

RESULTS AND DISCUSSION
Significant differences in the 1st peak KAM were observed for the conditions with AFO in the three different adjustments. Decreases of 8.1%, 10.9% und 11.9% in the 1st peak KAM were observed for the varus, neutral and valgus adjustments, respectively, compared with the baseline

condition. Similar reductions were observed in the knee joint angle and knee lever arm in the frontal plane at the moment of the first peak KAM (figure 2). No significant differences were observed for the second peak KAM, COP and GRF (components, resultant and vector inclination). No significant differences were observed between baseline and laterally wedged insoles for any parameter.

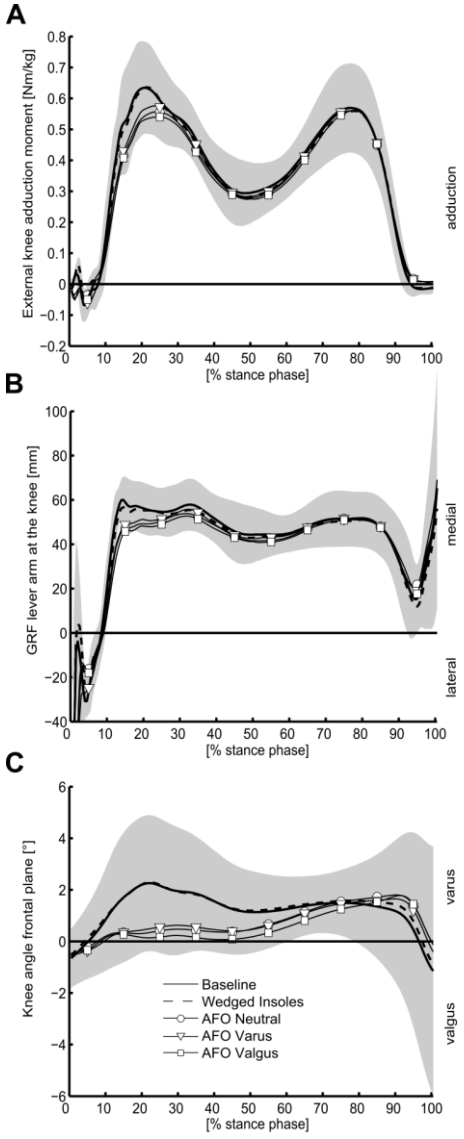

Figure 2: Mean curves of knee adduction moment, knee lever arm and knee angle in the frontal plane normalized through the stance phase for all subjects during the different test conditions. The shaded area indicates ± SD of the baseline condition.

The valgus adjustment of this orthosis should contribute to keep the tibia in a more vertical position, causing a decrease in the knee lever arm in the frontal plane and thereby decreasing the knee adduction moment. The varus adjustment should cause an opposite effect increasing the knee varus malalignment and the knee adduction moment. Significant decreases in those parameters were observed with the AFO in all three adjustments, which contradicts our expectations. It seems that the AFO, independent from the adjustment used, offers ankle stabilization avoiding the rotation of the shank in the frontal plane. By keeping the shank in a more vertical position, the knee lever arm in the frontal plane is shorter. Stabilization of the ankle joint was already pointed out in early studies as an important factor for the effectiveness of laterally wedged insoles [3]. According to those authors, kinematic changes in the subtalar joint induced by laterally wedged soles could be better transferred to tibia by strapping the ankle joint, avoiding compensating movements of the talus. Other authors also reported better unloading effect using a combination of wedged insoles and an ankle orthosis [4]. However, those authors used the ankle orthosis only as a stabilization element for the joint. The present study analyzed the effect of changing the orthosis alignment in the frontal plane to induce kinematic and/or kinetic changes at the knee joint. The combination of wedged insoles and the AFO was not analyzed in the present study.

This study aimed to analyze the mechanical mechanisms for reduction of the KAM. Therefore, subjects with knee varus alignment were recruited. In this sample of healthy individuals, no significant changes could be observed with wedged insoles. Individual responses to laterally wedged insoles are widely reported in the literature and it is known that some subjects do not respond positively to this therapy [5]. The reasons for these individual responses are not clear, but could be related to ankle joint stiffness of each subject.

CONCLUSIONS

Significant decreases of the knee adduction moment could be observed in subjects with knee varus alignment while using an ankle-foot-orthosis in different adjustments (4º valgus, neutral and 4º varus). The orthosis was effective in changing the knee joint alignment and the knee joint lever arm in the frontal plane. Long term effects on the knee adduction moment, symptoms and joint function in patients with medial knee osteoarthritis should be investigated in future studies.

The use of ankle-foot-orthoses designed to change the tibia position and thereby the knee joint alignment in the frontal plane could represent an alternative for conservative treatment of knee osteoarthritis.

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