INTRODUCTION

Medial compartment knee osteoarthritis (OA) is nearly 10 times more common than lateral compartment OA [1] and develops in approximately 20-40 % of adults over the age of 60 [2]. A high maximum knee adduction moment in walking has been associated with OA rate of progression, treatment outcome, and disease severity. The use of a shoe intervention with a more rigid lateral compared to medial midsole, referred to as a variable stiffness shoe (VS), can reduce the knee adduction moment magnitude in both healthy persons [3] and osteoarthritis patients[4]. Initial investigations with this VS shoe have also found that only a small portion of the variability in the absolute change in the maximum knee adduction moment is explained by the peak magnitude in a neutral shoe and that secondary changes in the hip and ankle frontal plane moments accompany changes in the knee adduction moment [3; 5]. These results suggest that an important dynamic response by the lower extremity muscles may be involved in the adaptation to this intervention and thus the reduction of the knee adduction moment during walking.

Changes in both joint kinetics and lower extremity muscle activation patterns in response to athletic footwear with subtle design variations in midsole density, stiffness or in combination with wedged inserts have previously been reported [6; 7]. These results suggest investigations into the effects of shoe interventions should consider muscle in addition to joint mechanics. With respect to the VSS shoe, the mechanism linking the specific variation in shoe mid-sole properties with the changes in joint mechanics remain unclear. Therefore the purpose of this study was to quantify the effect of a VS shoe on muscle activity in the lower extremity during walking. It is hypothesized that increases in the mean EMG intensity will occur in response to walking the VS shoe compared with a neutral control shoe.

METHODS:

Gait analysis was performed on five healthy volunteers (24 +/- 2 yrs; 1.63 +/- 0.05 m; 56.2 +/- 10.3 kg). Lower extremity joint kinematics were captured at 120 Hz using an 8 camera motion analysis system synchronized with an in-floor force platform to measure external ground reaction forces (GRF). Each subject performed three trials at their self-selected normal walking speed. Three dimensional net joint reaction moments were calculated using inverse dynamics. Two shoe conditions were tested: a control shoe with a uniform sole stiffness and an intervention variable stiffness shoe (VS) similar in construction to the control but with a midsole that is stiffer on the lateral compared to the medial side.

Bipolar surface EMG electrodes were placed on the gluteus medius (GM), biceps femoris (BF), tibialis anterior (TA), gastrocnemius medialis (MG) and lateralis (LG), and peroneus longus (PL) muscles according to the SENIAM recommendations[8]. Data were collected at 1200 Hz. The mean EMG intensities were determined for three time windows: a pre-activation phase (100 ms prior to heel-strike); a loading (0-50% of stance) phase; and a propulsion phase (50-100% of stance) of the gait cycle using wavelet techniques[9]. For each subject and muscle the EMG intensity was normalized to the average mean EMG intensity for the stance phase of the walking stride from the control shoe.

Statistics: Wilcoxon-sign rank tests were used to identify differences in the joint kinetics, GRFs and EMG intensities between the two tested shoe conditions. A confidence level of 90% was selected.
RESULTS

Kinetics: A reduction in the 1st peak adduction moment at both the knee and hip was found for the VS shoe compared to the control shoe (mean reductions of 12 and 13% respectively). Increases in both the ankle eversion and inversion moments were found for the VS shoe (18 and 45% respectively).

Forces: No differences in the total GRF magnitudes were found between the two shoe interventions. Small, but not statistically significant, reductions in the peak medial and peak lateral GRFs were found with the VS shoe.

EMG: Changes in the lower leg muscle EMG intensity were found in the pre-activation and loading phase time windows with VS shoe (p < 0.1). In the propulsion phase time window changes in the upper leg muscle EMG intensities were found (p < 0.1) (Fig. 1 a, b, c).

DISCUSSION

The preliminary results indicate changes in lower extremity muscle EMG intensities occur in response to a VS shoe. In agreement with previous results, reductions in the 1st peak knee and hip adduction moments and increases in both the ankle inversion and eversion peak moments were found.

The GRF vector direction and thus the joint moment magnitudes, are influenced by the relative position of the body center of mass with respect to the center of pressure. Increases in lateral muscle EMG intensity in stance, in particular the hip abductor and extensor (gluteus medius and biceps femoris) muscles, in response to the VS shoe suggest that a change in pelvic motion and contribute to the reduction in both the hip and knee adduction moments. The changes in EMG pre-activation intensities could produce a lateral rotation of the tibia at touchdown, or “toe-out” gait, and again contribute to the reduction of the knee adduction moment.

Interventions that result in a reduction of the knee adduction moment in walking are of interest because of the strong connections between the adduction moment magnitude and osteoarthritis disease status. The changes in selected muscle EMG intensities during the gait cycle for the VSS shoe suggest this intervention does not work in a purely passive mode, but that an active adaptation to the high lateral midsole stiffness occurs. It is not known how changes in the neuromuscular system in OA patients may impact the efficacy of this intervention. Our future work will aim to determine the specific relationships between EMG changes and changes in the frontal plane joint moments and to determine if similar muscle reactions are present in OA patients.

REFERENCES


![Fig 1](image)

Fig 1: Mean EMG intensities for the selected muscles for a) pre-activation, b) loading phase, and c) propulsion phase time windows. * indicates a statistically significant difference between shoes p< 0.1.