LOWER EXTREMITY MUSCLE ACTIVITIES AND GAIT KINEMATICS IN HIKING USING TREKKING SHOES AND HIGH-CUFF HIKING BOOTS

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The purpose of this study was to investigate the effect of high-cuff hiking boots on gait kinematics and lower extremity muscle activities compared with standard trekking shoes. 16 participants walked on a treadmill at 0°and 12° inclination uphill with both, a high-cuff hiking boot and a standard trekking shoe. Kinematics was collected with a 12 camera IR system. The activities of the mm. tib. ant., soleus, gastroc., rect. fem., vast. lat. and bic. fem. was recorded. For all muscles substantially higher muscle activities have been found for the uphill condition. While the activity of the mm. bic. fem. and tib. ant. was higher using high-cuff hiking boots, the activity for the mm. gastroc., soleus and vast. lat. was reduced. These results might help to understand more specifically the effect of footwear in hiking in general and to support the development of hiking footwear.

KEY WORDS: hiking footwear, EMG, gait kinematics

INTRODUCTION: Hiking and mountaineering are very common sport activities in the Alpine regions and have developed as popular leisure sport (Pratscher, 2000). Based on the enhanced number of hikers also the amount of accidents and injuries increased substantially in hiking and mountaineering (ÖAV, 2016; DAV, 2015). Beside physical and technical demands also aspects of safety and equipment have to be considered in this regard with a specific focus on footwear. For preventing ankle sprain, over-supination traumata, bruises and abrasions most of the hikers prefer hiking boots with high cuffs. Only few studies are presented in the literature investigating the effect of high vs. low cuff footwear on gait kinematics and lower extremity muscle activity. Koukoubis, Kyriazis, & Rigas (2003) showed a change of spatio-temporal parameters in hiking with high cuff boots compared with low cuffs with an increase of the double-support phase and a reduction of the single-support phase. Furthermore, the reduction of the range of motion in the ankle joint cannot directly lead to enhancing stance stability. An increase of the variability of gait parameters was found to be correlated with an increase of falls (Hausdorff, Rios, & Edelberg, 2001). Hösl, Böhm & Senner (2010) studied the effect of cuff stiffness of hiking boots on the muscular activity and the efficiency of walking on uneven, flat surfaces. It was reported that stiffer cuffs reduced the ankle range of motion and reduced the walking efficiency by enhanced co-contractions primarily of knee spanning muscles.
So far the literature does not present studies looking at gait kinematics and lower extremity muscle activities using different footwear. Thus, the purpose of this study was to investigate the effect of high-cuff hiking boots on gait kinematics and the activity of selected lower extremity muscles compared with standard trekking shoes without cuff.

METHODS: Sixteen healthy, physically active participants with extensive mountaineering experiences (7 male, 9 female, 29 ± 9 yrs; min. 15 hiking tours/yr) have been recruited for this study. They had to walk on a treadmill (Pulsar LT3P, hp-cosmos) at a speed of 1.11 m/s in level condition (0°) as a reference with trekking shoes and at 12° inclination uphill both with high-cuff hiking boots and trekking shoes (both own and individual equipment; examples in Figure 1a and 1b). For all conditions 15 gait cycles were recorded, 10 out of these were selected for further analysis.
The kinematics of the lower extremities and the shoes were collected with a 12 camera motion capture system (Vicon, Oxford Metrics, Ltd., UK) at 250 Hz using the Cleveland Clinic marker set with additional markers on the boots. The muscle activities of the m. tibialis anterior, m. soleus, m. gastrocnemius lateralis, m. rectus femoris, m. vastus lateralis and m. biceps femoris of the right leg was recorded with standard surface EMG (Myon 2.0) with 1000 Hz sampling frequency.

Skin preparations and electrode placement were conducted according to Hermens et al. (1999) and SENIAM (www.seniam.org) recommendations. The EMG data were normalized to the 0° reference conditions (mean activity over one stance phase using the trekking shoe). Kinematic and electromyo-graphic data were analysed using Visual3D (c-motion, Inc, Rockville, USA). The gait cycle was defined from heel strike to the consecutive heel strike and 10 cycles per conditions were averaged.

Figure 1a: Trekking shoe (example)

Figure 1b: High-cuff hiking boot (example)

This abstract only presents selected EMG data from one typical participant, but no kinematic analysis. For this reason only descriptive statistics have been executed. The entire data set will be presented at the conference.

RESULTS: Table 1 presents the average muscle activity over the stance phase (in arbitrary units) of six lower extremity muscles for the three conditions and, additionally, the difference between uphill walking with trekking shoes and hiking boots. The related values relative to the 0° trekking shoe condition including the percentaged differences between the two 12° conditions are shown in Figure 2. The average muscle activity in the two uphill conditions is between 1.4 and 3.3 times higher than the activities during level walking with trekking shoes.

Table 1: Mean muscle activity (arbitrary units) in level walking (0°) with trekking shoes and uphill walking (12°) with trekking shoes and high-cuff hiking boots including the differences between the two uphill walking conditions.

EMG [a.u.]	slope	biceps femoris	gastro-cnemius	rectus femoris	soleus	tibialis anterior	vastus lateralis
trekking	0°	198	211	105	321	427	154
trekking	12°	340	687	152	561	594	324
high cuff	12°	379	625	156	458	821	308
Δ (trek-high cuff)	12°	40	-62	4	-103	227	-15

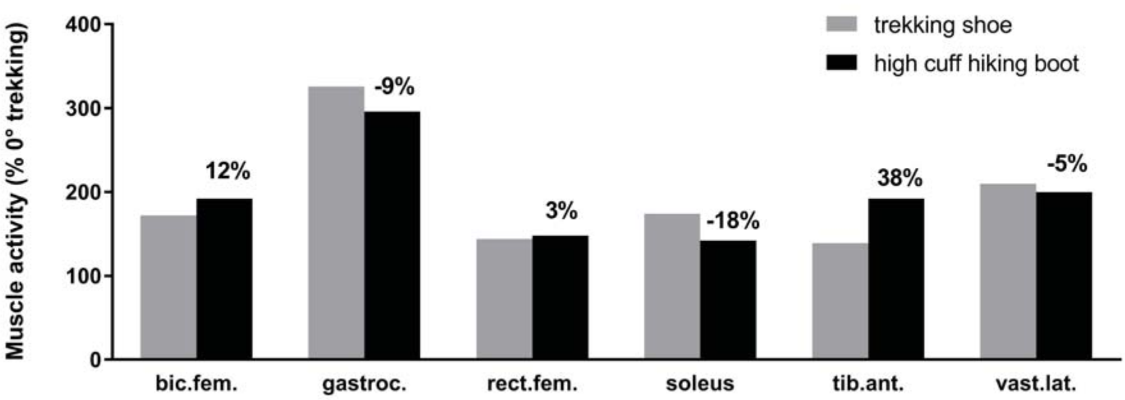

Figure 2: Mean muscle activity (% of 0° trekking shoe condition) for 12° trekking shoe and 12° high cuff boot condition including the percentaged differences between the two conditions.

The m. tibialis is affected most by the footwear. High-cuff boots increased the average activity by almost 40%. Changes in the same direction, but to a lesser extent can be observed for the m. biceps femoris. M. gastrocnemius, m. soleus and m. vastus lateralis, however, show less activity when walking uphill with high-cuff boots. Hardly any changes are seen for the m. rectus femoris.

DISCUSSION AND CONCLUSION: The analysis of the muscle activities comparing uphill walking with the two shoe conditions served plausible results. The restriction regarding the range of motion of the ankle joint with high-cuff boots leads to a reduced activation of the plantar flexors (m. gastrocnemius and m. soleus). During walking ankle and hip strategies have been discussed (Winter, 1995) and with an increase in biceps femoris muscle activity it could be that the use of high-cuff hiking boots induce a hip strategy during uphill walking. On the other hand, the ankle joint restriction with high-cuff boots leads to a substantial increase of the m. tibialis anterior activity. This can be explained by the additional dorsal extending force needed for safe toe clearance during uphill walking, possibly also caused by the additional weight of the boot. The differences of the activities of the remaining muscles investigated are relatively small, so no further discussion seems meaningful based on the single case data set. The changes of muscle activities have to be discussed along with the kinematics, which cannot be provided on the current stage of the analysis.
These results might help to understand more specifically the effect of footwear in hiking in general and to support the development of hiking footwear.

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