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Muscle activation during fast walking with two types of foot orthoses in participants with cavus feet

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ABSTRACT

The aim of this study was to quantify the effects of foot orthoses (FOs) with and without a lateral bar on muscle activity of participants with cavus feet. Fifteen participants were recruited from the Université du Québec à Trois-Rivières students and podiatry clinic. The muscle activity of the tibialis anterior, fibularis longus, gastrocnemius lateralis and medialis, vastus medialis and lateralis, biceps femoris and gluteus medius were recorded during fast walking under two experimental conditions (FOs with and without a lateral bar) and a control condition (shoes). Experimentations were completed after a one-month adaptation period to each experimental condition. The root mean square of the electromyography (EMG) data was analyzed. To compare the effects between conditions, a curve analysis was performed using one-dimensional statistical parametric mapping. The main result of this study was an increased gastrocnemius lateralis muscle activity (maximum mean difference: +28%) during the propulsion phase of gait (44–46%) when participants wore FOs compared to the control condition. This result will help researchers and clinicians better understand the FOs' EMG effects of individuals with cavus feet. As FOs are mainly prescribed for symptomatic patients, future studies should assess their effects on individuals suffering of a pathology, such as Achilles tendinopathy.

1. Introduction

Foot orthoses (FOs) are often used to manage, with an overall good efficacy, numerous musculoskeletal pathologies such as posterior tibial tendon dysfunction (Kulig et al., 2009), patellofemoral pain syndrome (Munuera and Mazoteras-Pardo, 2011) and medial tibial stress syndrome (Loudon and Dolphino, 2010). Their effects on muscle activity could perhaps explain their efficacy as numerous studies have demonstrated that they affect muscle activity during walking (Dedieu et al., 2013, Moisan and Cantin, 2016, Murley et al., 2010a). It has also been shown that, by adding modifications to FOs, it is possible to modulate muscle activity (Moisan and Cantin, 2016, Mundermann et al., 2006) during locomotion. FOs modifications can be described as any material you remove or add to the orthoses to increase their specificity. One of these modifications is a lateral bar. This modification was described by Moisan and Cantin (2016) as a one-centimeter wide ethylene-vinyl-acetate (EVA) bar glued under the lateral part of the FOs lying from the extrinsic rearfoot post to the distal end of the shell. The utilization of the lateral bar is based on the subtalar axis location rotational equilibrium (SALRE) theory (Kirby, 2001) according to which any force acting laterally to the ankle and subtalar joint axes will produce a pronatory moment around these joints. Consequently, the addition of a lateral bar should decrease pronatory muscles activity. In fact, it has been observed that FOs with a lateral bar decrease the fibularis longus muscle activity during walking (Moisan and Cantin, 2016). In clinical contexts, lateral bars are used to treat patients with pain or discomfort associated with excessive rearfoot supination moments during gait or injuries to lateral ligaments and muscles of the ankle and leg, such as chronic ankle instability and fibular tendinopathy. However, the effects of this modification have never been studied in individuals with cavus feet. These individuals present increased peak pressures under the rearfoot and pressure–time integrals under the rearfoot and forefoot (Burns et al., 2005), less peak ankle eversion (Powell et al., 2011) and more lateral ground reaction forces (Hillstrom et al., 2013) compared to individuals with flatter feet during walking. The differences in muscle activity between individuals with cavus feet compared to those with flatter feet are still poorly documented. However, according to the SALRE theory (Kirby, 2001), it can be hypothesized that individuals

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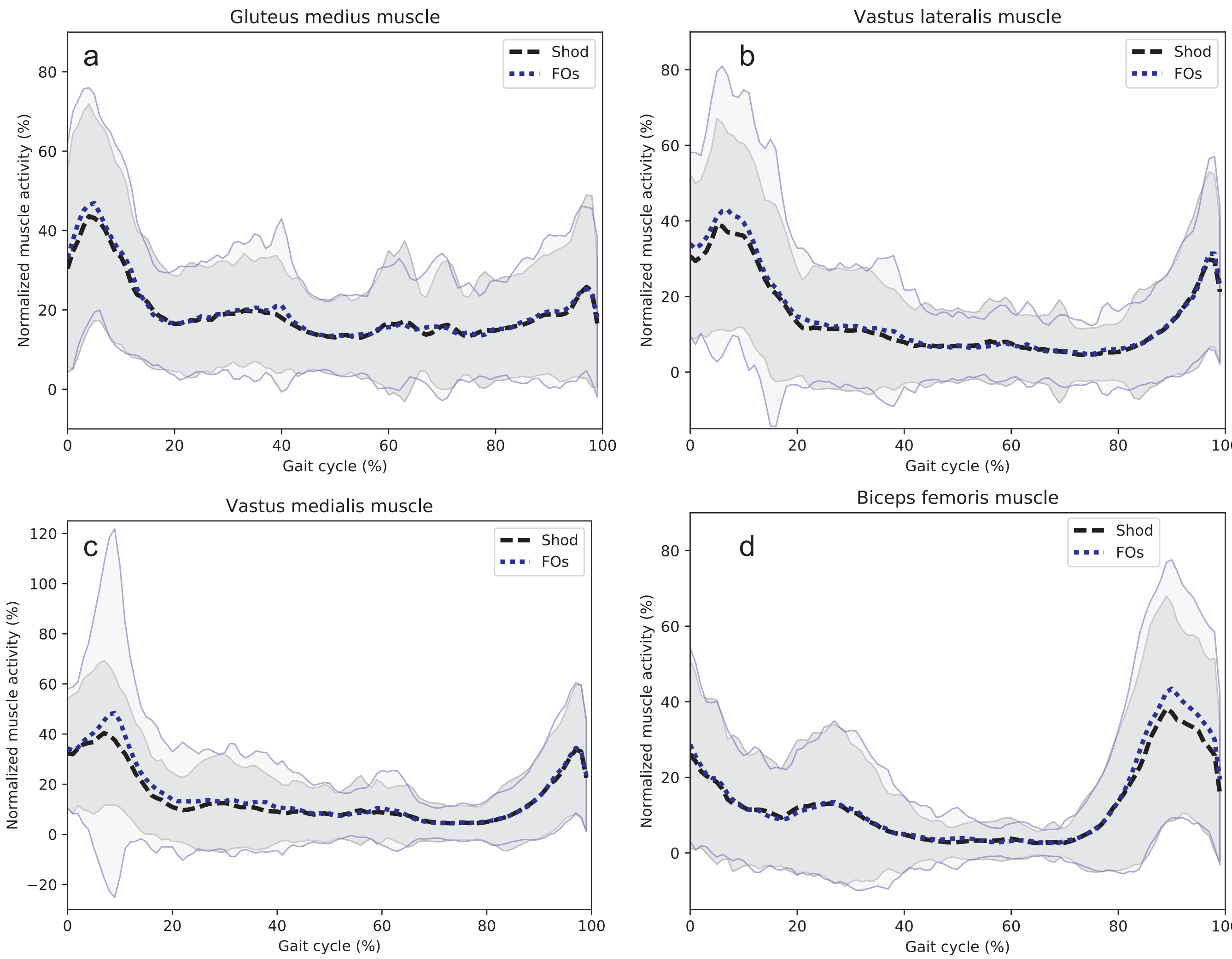

Fig. 1. Muscle activity with shoes and FOs.

with cavus feet present a laterally deviated subtalar joint axis. This deviation could decrease the level arm of the pronator muscles and therefore increase the activity of these muscles.

Previous studies assessing the effects of FOs on muscle activity during walking used a self-selected (Dedieu et al., 2013, Moisan and Cantin, 2016, Murley and Bird, 2006, Murley et al., 2010a, Telfer et al., 2013a) or a predetermined speed (Tomaro and Burdett, 1993). It has been demonstrated that muscle activity of the lower limb increases at faster walking speeds (Chiu and Wang, 2007, Den Otter et al., 2004, Murley et al., 2014). However, FOs' effects at a fast walking pace have not been quantified. It is then unknown if FOs have similar effects on muscle activity when walking at a faster pace. Therefore, there is a need to assess the effects of FOs on muscle activity at a fast walking speed, as it could have clinically important implications. It will help better understanding the underlying mechanisms explaining the FOs' therapeutic efficacy.

The FOs' effects on muscle activity are regularly studied in the literature, but according to Pataky et al. (2016), the analyses used in the previously published studies could be problematic. Indeed, by having a time component, muscle activity data are considered one-dimensional. However, in most previous studies assessing the effects of FOs on muscle activity, electromyography (EMG) data were analyzed with variables that are a zero-dimensional representation (punctual representation), such as timing (Dedieu et al., 2013, Moisan and Cantin, 2016, Murley and Bird, 2006, Murley et al., 2010a), peak activity (Murley and Bird, 2006, Murley et al., 2010a, Telfer et al., 2013a) and mean activity (Moisan and Cantin, 2016, Murley et al., 2010a, Telfer et al., 2013a, Tomaro and Burdett, 1993). It has been previously found that performing these zero-dimensional analyses (timing, peak or mean activity) produce a high rate of false positive results (Pataky et al., 2016). A false positive is observed when an effect is inferred but in fact, none exists. The convention in most biomechanics studies is to set α at 0.05, which implies that one accepts a 5% false positive rate when conducting the hypothesis testing. However, Pataky et al. (2016) found that for biomechanical data (EMG, kinematics and kinetics), the median false positive rate was 0.382 and was as high as 0.764 for variables with a three-dimensional vector (e.g. joint angles during gait). The high false positive rate could be explained by the fact that hypotheses pertaining to one-dimensional data are tested using a traditional zero-dimensional Gaussian model of randomness, but variance in these datasets is unidimensional. To avoid this problem, it has been suggested to use unidimensional procedures, such as one-dimensional statistical parametric mapping (SPM) (Pataky, 2012, Pataky et al., 2016).

The main objective of this study was to quantify the effects of FOs with and without lateral bar on muscle activity of participants with cavus feet. It was hypothesized that FOs will decrease pronator muscles activity and increase supinator muscles activity.