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Changing the texture of footwear can alter gait patterns

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Abstract

The foot provides an important source of afferent feedback for balance and locomotion. Sensory feedback from the feet can be altered by standing or walking on different surfaces. The purpose was to determine the effects of textured footwear on lower extremity muscle activity, limb kinematics, and joint kinetics while walking. Three-dimensional kinematics and kinetics, as well as muscle EMG, were collected as subjects walked with a smooth and textured shoe insert. Muscle activity was analyzed using a wavelet technique. The textured shoe insert caused a significant reduction in both soleus and tibialis anterior intensity during periods when these muscles are most active. Furthermore, the changes in muscle activity were only seen in the low frequency content of the EMG signal. The foot was significantly more plantar flexed at heel strike with the textured inserts. Small changes were also seen in vertical ground reaction forces and joint moments. It was assumed that the changes in gait patterns were due to a change in sensory feedback caused by the textured shoe insert. The possibilities of altered sensory feedback with footwear are discussed. Sensory feedback from the feet may affect specific motor unit pools during different activities. Changing the texture, without changing the geometry, of a shoe insert can alter muscle activity during walking. This may be useful in the prescription of footwear interventions and suggests that footwear may have sensory as well as mechanical effects.

Keywords: Afferent; Sensory feedback; Biomechanics; Shoe inserts; Muscle; EMG; Wavelet; Kinematics; Footwear

1. Introduction

The human foot is the first point of contact between the body and the external environment, and is ideally positioned to provide sensory information to the central nervous system during static and dynamic tasks. An important source of sensory feedback comes from specialized mechanoreceptors found within both the hairy and glabrous skin of the foot. Afferent feedback from these receptors has been studied in both animal and human models, and in different experimental settings.

Afferent feedback from the feet is important for balance and locomotion. During static postural tasks, cutaneous feedback originating from specialized mechanoreceptors in the foot is thought to have a strong influence on balance stability [16,20] and postural correction strategies [9,17]. While walking and running, both noxious [4] and non-noxious [11] stimulation of cutaneous nerves that innervate the foot can affect α-motoneuron activity in the muscles of the legs, most likely via Aβ reflex pathways [38]. Changes in lower extremity kinematics have also been reported following cutaneous stimulation during the gait cycle [11,41].

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During gait, reflexes are dependent on the task, muscle, phase of the step cycle, and location and intensity of the stimulus [12,28,37,40]. However, electrical stimulation of cutaneous nerves and the study of muscle reflexes does not provide information about the effects of long term changes in cutaneous sensory feedback.

Sensory feedback from the feet may be influenced by changing the characteristics of a shoe sole or surface. Watanabe and Okubo [36] provided evidence that standing on different surfaces can alter the transmission of afferent signals from the plantar surface of the foot. Increased tibial nerve activity was seen when standing on surfaces that were textured with varying densities of semi-circular shot pellets. Wu and Chiang [39] showed differences in the latency of muscle reflexes after perturbations when standing on soft surfaces. The authors implied that sensory feedback from the feet was altered when standing on the different surfaces. Maki and coworkers [21] showed a qualitative improvement in balance recovery in young and elderly populations when sensory feedback was thought to be enhanced with special tubing attached to the subject's feet, although no direct evidence of increased sensory feedback was provided. These studies examined the effects of a prolonged change in sensory feedback during postural tasks. However, these effects have not been examined during cyclical movements, such as walking or running. Specifically, the effects of footwear induced changes in sensory feedback on human gait patterns have not been studied in a normal population.

It has been recently speculated that the ability of shoe inserts or orthoses to alter joint kinematics or kinetics may be influenced by sensory feedback from the feet [23,27]. Subject specific differences in sagittal plane kinematics and joint kinetics have been attributed in part to sensory mechanisms. These speculations have not been justified. By altering on the only the texture, but not the shape of a shoe insert, the effects of altered sensory input can isolated and examined without the confounding effects of mechanical shape changes.

Therefore, the purpose of this study was to determine the effects of textured footwear on lower extremity muscle activity, limb kinematics, and joint kinetics while walking. It was hypothesized that the use of textured inserts would result in: (a) significant differences in muscle activity at different phases of the step cycle; (b) significant differences in sagittal plane limb kinematics; and (c) no differences in joint kinetics or impact forces.

2. Methods

Fifteen subjects, 12 males and three females, volunteered to participate in this study (mean ± SD age: 24.7 ± 2.9 years; height: 177 ± 9 cm; weight: 74 ± 12 kg). All subjects reported that they were free of any known neurological dysfunction or physical impairment that might affect their performance in this test. Ethics approval was obtained from the university's Office of Biomedical Ethics. All subjects were properly informed about the nature of this study and signed written consent forms prior to their participation.

2.1. Experimental protocol

Subjects were required to walk at a speed of 1.5 m s^{-1} along a 30-m indoor pathway in two shoe insert conditions. The speed of walking was controlled with infrared timing lights placed 1.90 m apart. The control insert was made from 3 mm thick EVA foam (shore C 60) that was cut to standard foot insert sizes. The textured insert was a 3 mm thick EVA foam insert that was cut from a commercially available sandal. It was textured with semi-circular mounds with center distances of 8 mm (Fig. 1). The textured insert was worn with the textured side up, in contact with the plantar surface of the feet. It was easily detected by all subjects and strong enough to elicit a distinct preference or dislike for the insert. Shoes were not used. The heel area of the shoe inserts was sprayed with sticky medical adhesive (Hollister Inc. Libertyville, IL) to help hold the insert to the subject's bare feet. A nylon stocking was then placed around the foot to hold the insert in place. Thin elastic wrap (Underwrap, Cramer Products Inc., Gardner, KS) was

Fig. 1. Pictures of the smooth (left) and textured (right) inserts used in this study.