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Effects of different unstable sole construction on kinematics and muscle activity of lower limb

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ABSTRACT

Unstable sole construction can change biomechanics of lower extremity as highlighted by some previous studies, which could potentially help developing special training or rehabilitation schemes. In this study, unstable elements are fixed in heel and forefoot zone to exert unstable perturbations, and the position changes (medial, neutral and lateral) of unstable elements in forefoot coronal plane are adjusted to analyze changes of lower extremity kinematics and muscle activities. Twenty-two healthy male subjects participated in the test, walking with control shoes and experimental shoes randomly under self-selected speed. Kinematics and surface electromyography measurements were carried out simultaneously. It is found that experimental shoes can lead to the reduction of knee abduction and internal rotation and hip internal rotation, with $p < .05$. Ankle inversion and internal rotation amplitude were also reduced, which are associated with significantly increased activation levels of muscles (TA-tibialis anterior, PL-peroneus longus, LG-lateral gastrocnemius) in order to compensate perturbations. It is suggested that a training equipment incorporating unstable elements would enhance postural control by adjusting lower extremity kinematics and reorganizing muscle activity. More research can be conducted to testify the feasibility of unstable shoes construction on human postural control and gait, even guide training regime design, injury prevention and rehabilitation.

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1. Introduction

Footwear has been traditionally applied to maintain or improve posture stability during daily activities (Reinschmidt & Nigg, 2000). However, it is possible that the function of conventional shoes such as stabilization and supporting may protect/constraint feet excessively, resulting in the hypofunction or deterioration of the small extrinsic muscle groups in lower extremity (Jackman & Kandarian, 2004; Nigg, 2009). This could lead to the decline of muscle strength or even potential muscle injuries (Nigg, Hintzen, & Ferber, 2006; Sousa & Tavares, 2012). Based on these considerations, more and more studies have been focused on the function of unstable shoes, like *MBT* (*Masai Barefoot Technology*) and *RC* (*Reflex Control shoes*) (Turbanski, Lohrer, Nauck, & Schmidtbleicher, 2011), in injury prevention, balance control or postural control in dynamical situations. These functions are essential in training of proprioceptive ability, sensorimotor ability and neuromuscular ability, with the unstable outsole construction allowing more organic functions cooperating at the same time. Theses functional shoes were designed with the idea of "barefoot shoes", providing the effect of balancing inner and outer motor ability. Based on some published research works the key functional benefits of unstable shoes could be summarized as producing defined instability and increased postural stability and muscle activity, reducing perceived the level pain, strengthening muscles of lower limbs and rehabilitating lower extremity or lower back injuries (Nigg, Federolf, Tscharner, & Nigg, 2012), absorbing shock in initial contact phase (0–10%) (Taniguchi, Tateuchi, Takeoka, & Ichihashi, 2012), adjusting postural control system and improving performance (Sousa, Macedo, Santos, & Tavares, 2013).

The design concept of unstable shoes originated from the idea of unstable training equipment, such as MBT which stem from wobble boards training with the function of improving performance and reducing risk of injury (Stöggl, Haudum, Birklbauer, Murrer, & Müller, 2010; Waddington & Adams, 2004). The sole is characterized by a convexity which provides an unstable support base while standing or walking in order to increase muscle activity, improve proprioception effectively and increase muscle strength and muscle coordination by increasing postural control (Stöggl et al., 2010; Turbanski et al., 2011). To alleviate the deterioration of muscle function, unstable shoes are widely exploited, investigated and promoted for the benefits of combined advantages.

The change of gait characteristics can affect the capacity of stability during walking (Nigg et al., 2012). The body adjust motor pattern to respond to different inner or outer perturbations, for example, loading variations, injury risks and postural control system reorganization (Fisher, Dyrby, Mundermann, Morag, & Andriacchi, 2007; Sousa et al., 2013). This may be due to different motor patterns stimulating the body to adapt to inner and outer stimulus and maintaining co-activation of proprioceptive system, sensorimotor system, postural control system and neuromuscular system in a specific biomechanical load range to avoid hypofunction or even injuries (Hardin, van den Bogert, & Hamill, 2004; Sousa et al., 2013). Previous studies have shown that the ability of controlling posture, the movement of COM (center of mass) and the plantar pressure zone are inter-linked with each other (Lee & Chou, 2006; Winter, 1995). It has been reported that gait characteristics changes greatly, and the frequency of falling increases in the study on the population of nerve hypofunction (Grabiner, Biswas, & Grabiner, 2001; Hausdorff, Balash, & Giladi, 2003; Hollman, Kovash, Kubik, & Linbo, 2007; Schaafsma et al., 2003), and most fallings was found to occur during dynamic situations (Voermans, Snijders, Schoon, & Bloem, 2007). Gait instability became an crucial factor of falling-down, which is prevalent in patients with knee arthritis, Parkinson's disease, diabetes and some other lower limb neuromuscular injuries (Arnold & Faulkner, 2007; Factor et al., 2011; Lavery, Vela, Lavery, & Quebedeaux, 1997). In addition, falling becomes a significant and non-negligible factor in the elderly (Turbanski et al., 2011; Voermans et al., 2007). One responding effect of wearing unstable shoes long-term is training small muscle groups of lower extremity, especially slow twitch muscle fibers, which will promote the stabilization of joint muscles, so as to improve the balancing ability of the subjects (Nigg et al., 2012).

The capacity of dynamic stability in gait can be determined by analyzing the kinematic difference and muscle activity during the same phase of gait cycle (Goryachev, Debbi, Haim, et al., 2011). Different soles that are devised according to biomechanics (heeled, negative heel, round, etc.), can effectively influence the motor pattern of lower limb, and changes of the unstable sole construction can cause a distinct change of gait kinematics and muscle activity (Debbi, Wolf, & Haim, 2012).