THE EFFECT OF ARCH-SUPPORTED FUNCTIONAL INSOLES TO AVOID OVERUSED INJURIES DURING RACE WALKING

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This study investigates the effectiveness of functional insoles on plantar pressure distribution during race walking in order to reduce the high plantar pressure and force on race walkers, who tend to suffer from overuse injury. A total of 20 male race walkers were recruited as subjects. Each participant completed a race walk with and without functional insoles. Plantar pressure insoles were used to collect plantar pressure data. A two-way analysis of variance with a mixed design was used to determine the difference between the two conditions. Results show that the use of functional insoles reduced the peak pressure and the impulse in the metatarsal heads and heels and thus suggest that functional insoles reduce the overuse injury risks of these parts. The first ground reaction force peak also decreased. This result suggests that functional insoles reduce the risks of foot and leg injuries.

KEY WORDS: PLANTAR PRESSURE, PEAK PRESSURE, FORCE

INTRODUCTION: Race walking, particularly the 5 and 10 km events, has grown in popularity in recent years and is rapidly becoming the favored pastime of recreational athletes (Francis, 1998). This trend possibly results from the belief that race walking is a sport that provides valuable health and fitness benefits and has low risk of injury (Kummant, 1981). However, researchers consider race walking as a sport event with a high risk of injury. Francis (1998) conducted a questionnaire study on 682 race walkers and found that approximately two-thirds of the respondents had suffered one or more injuries in the course of their race-walking careers. Sanzen (1986) noted that 90% of the race walkers they examined complained of pain during walking. In the remaining 10%, the pain was reportedly felt throughout the race. Palamarchuk (1980) interviewed 31 race walkers and found that their primary injuries were blisters on the metatarsals, heels, and toes, as well as hamstring injuries and medial knee pains.

Race walking is an endurance event that requires athletes to walk 20 km to 50 km. Fifty-kilometer race walking is the longest track and field event and involves distances that are approximately 7.8 km longer than those in marathons. A 67 kg individual walking 50 km must absorb 2016 tons on each foot (Dowling 2008). Thus, race walkers are prone to overuse injuries, such as blisters, metatarsalgia, stress fractures, and knee pains, in their lower extremities. During race walking, walkers have to recurrently undergo plantar compressive loading for 1 h to 4 h; during this period, the regions experiencing relatively high pressures or forces, such as the metatarsal heads and heels, readily suffer from overuse injury.

For diabetics, orthotic insoles and pressure relief shoes reduce plantar pressure loading (Ibrahim 2012; Raspovic 2012). In a similar manner, race walkers are at high risk of plantar pressure-related overuse injuries (Palamarchuk 1980; Song 2013). In this study, arch-supported functional insoles (International Biomechanics Limited) were used to reduce plantar pressure loading during race walking. The insoles were expected to increase the arch height as well as the cushion beneath the heel. The loads on the metatarsal heads and heels were transferred to the arch area to reduce the peak pressure and the GRF in the metatarsal heads and heels as well as the risk of overuse injuries in these areas. This study aims to determine the effects of functional insoles on the plantar pressure distribution during race walking. We hypothesized that the functional insoles change the plantar pressure distribution by reducing the peak pressure on the metatarsal heads and heels and reduce the ground reaction forces (GRF) upon landing.

METHODS:
Subjects: A total of 20 male race walkers aged 21.19 ± 3.66years were recruited from the provincial race walking team of Shandong, China. The subjects had a mean height of 178.85 ± 14.07cm, a race walking history of at least 5 years, and no history of lower limb pathology at the time of the study or in the preceding six months. **Testing Protocol:** Each participant did race walking at 80% of their maximum walking speed for 400 m in his or her own race walking shoes in two conditions: (1) with functional insole (functional insoles placed in both shoes), and (2) without functional insole. **Data Collection:** Plantar pressure insoles (Rs-scan International, Olen, Belgium) were used to collect plantar pressure data. How was the GRF collected? **Data Reduction:** During our test, peak pressures of eight anatomical sub-regions, GRF of the whole foot were calculated. Eight anatomical sub-regions were identified as the medial heel (Hm), lateral heel (Hl), medial arch (Vm), lateral arch (Vl), metatarsal joints 1 to 5 (M1, M2, M3, M4, and M5) and the hallux (T1). **Data Analysis:** Two-way analysis of variance (ANOVA) with mixed design was used to compare plantar pressure among ten different parts of the foot and between two conditions. Condition was a repeated measure while foot part was an independent measure. If no significant interaction effect of condition and foot part on plantar pressure was found but a significant main effect of foot part was found, independent t-tests would be performed to locate differences in plantar pressure among foot parts. If a significant interaction effect of condition and foot part on plantar pressure was detected, one-way ANOVA with repeated measures would be performed to compare plantar pressure between conditions for each foot part, and among foot part for each condition.

RESULTS: During data analysis, the condition and foot portion showed no significant interaction effect on the plantar pressure. With normal insoles, the highest pressure was found on the metatarsal and heel areas. The functional insoles reduced the pressures in these areas and increased the medial arch. With functional insoles, the peak pressures significantly decreased in T1 ($p = 0.012$), M1-4 ($p = 0.005, 0.000, 0.002$, and 0.031), Hm ($p = 0.000$), and Hl ($p = 0.000$) compared with those with normal insoles (Figure 1), but increased in Vm ($p = 0.000$) and did not change in M5 ($p = 0.159$) and Vl ($p = 0.173$).
Meanwhile, the GRF exhibited a normal bimodal pattern. With functional insoles, the first peak decreased ($P = 0.034$) but the second peak remained unchanged ($P = 0.078$) (Figure 2).

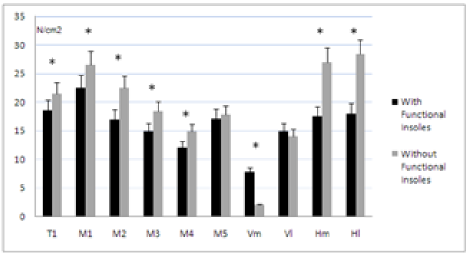

Figure 1: Peak pressures on plantar areas
*Significant difference between two different insole conditions

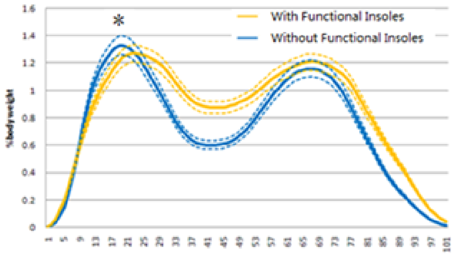

Figure 2: GRF
*Significant difference between two different insole conditions

DISCUSSION: The current study demonstrated that the arch-supported functional insoles reduce the highest peak pressures and impulse on the metatarsal heads and heels and the GRF of the first shock. These findings coincide with those of previous studies. Ibrahim (2012) noted that in the treatment of diabetics, orthotic insoles and pressure-relief shoes reduce plantar pressure loading.

Race walkers repeatedly undergo foot loading approximately 18,000 to 48,000 times during a single race (Hanley 2011). The offloading of pressure during each step greatly reduces the risk of overuse injury. The arch-supported mechanism of the functional insoles shifts the load from the forefoot and hindfoot toward the midfoot; thus, the pressures on the forefoot and barefoot are reduced (Redmond 2000; Bus, 2012). Our study showed that functional insoles significantly reduce the peak pressures in the toes, metatarsals 1 to 4, and heels, all of which are vulnerable to injuries (Werner 2010). Furthermore, repetitive submaximal stimuli can reduce the individual loading capacity of the bone and lead to structural changes in the areas of maximal stress (Karagounis 2009).

After a long period of repeated foot loading, the plantar load is transferred from the toes to the metatarsal heads and causes higher peak pressures in the metatarsal areas compared with that at the start of walking or running; this repeated loading may lead to stress fractures in the metatarsal bones, particularly in the 2nd and 3rd metatarsals, which are vulnerable because of the discrepancy between the bone strength and imposed plantar pressure (Karagounis 2009). The functional insoles reduce the risk of overuse injury by offloading the peak pressure on the metatarsal heads. This reduced pressure is more helpful for long-distance track events, such as race walking or marathons. Functional insoles also reduce the peak pressures on the heels for three reasons: (1) the medial arch support transfers the loads from the heels toward the midfoot area; (2) the heel cup structure realigns the calcaneus to a more normal position and redistributes the pressure in prefabricated orthosis; and (3) the thicker and softer materials of the insoles help absorb pressure.

Chiu (1996) noted that the peak strength emerges after the heels first come into contact with the ground. This peak strength causes vibrations in the lower limbs. Therefore, people often adjust their gait to avoid maximum pressure when excessive pressure is exerted on their feet. During normal walking or running, people can bend their knees to cushion against excessive pressure. However, official race walking rules (i.e., International Association of Athletics Federation) state that the supporting leg must be fully extended during its period of contact. This leg extension limits the cushioning by the knee joints during race walking. As a result, the first GRF peak is significantly greater during race walking than during normal walking (Song

2013) and generates strain in the midtibial musculoskeletal structures. The overloading of the musculoskeletal system can result in overuse injuries. The decrease in the first peak force indicates that the insoles absorb the vertical shock during the strike phase of the heels and thus reduces the risk of injury on the foot and leg.

CONCLUSIONS: During race walking, the peak pressure in the metatarsal heads and heels are reduced by arch-supported functional insoles. As such, functional insoles can prevent overuse injuries by offloading the peak pressures in the metatarsal heads and heels and reduce the risk of overuse injuries in these parts. The reduction in the first GRF peak also suggests that the insoles absorb the vertical shock during the strike phase of the heels and thus prevent the injuries in the foot and leg.

ACKNOWLEDGEMENT: This paper is supported by the ISBS 2013 Student's Mini Research Grant.

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