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Full Length Article

Effects of duration of wearing high-heeled shoes on plantar pressure

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ABSTRACT

In the present study we investigated the effects of different durations of using high-heeled shoes on plantar pressure and gait. A questionnaire survey and dynamic plantar pressure measurements were performed in 20 control females and 117 females who had worn high-heeled shoes for a long time. According to the duration of using high-heeled shoes (as specified in the questionnaire), subjects were divided into a control group and five groups with different durations of use (i.e. <2 years, 2–5 years, 6–10 years, 11–20 years and >20 years). Parameters, including peak pressure, impulse and pressure duration, in different plantar regions were measured with the Footscan pressure plate. The 2–5 years group had smaller midfoot contact areas for both feet and higher subtalar joint mobility, while the 6–10 years group had larger midfoot contact areas for both feet and prolonged foot flat phase during gait. The peak pressure and impulse under the second and fourth metatarsus were increased with the prolonged wearing of high-heeled shoes, and the pressure and impulse under the midfoot were substantially reduced in the 2–5 years group. The findings suggest that long-term use of high-heeled shoes can induce changes in arch morphology: the longitudinal arch tends to be elevated within 2–5 years; the longitudinal arch tends to be flattened within 6–10 years; and the forefoot latitudinal arch tends to collapse in more than 20 years.

1. Introduction

High-heeled footwear is one of the most important fashion accessories and contributes to a taller and more slender body shape in female wearers (Guéguen, 2014). The body's center of mass is moved forward in wearers of high-heeled shoes, who must lift up the breasts, protrude the buttocks and stretch the waist backward to keep the body balanced (Chien, Lu, & Liu, 2014). Therefore, long-term use of high-heeled shoes causes paraspinal muscle fatigue (Mika, Oleksy, Mikolajczyk, Marchewka, & Mika, 2011), low back pain (Barton, Coyle, & Tinley, 2009; Mika, Oleksy, Mika, Marchewka, & Clark, 2012a; Russell, Muhlenkamp, Hoiriis, & Desimone, 2012) and leg muscle injury (Kim, Yi, Yoo, & Choi, 2011; Mika, Oleksy, Mika, Marchewka, & Clark, 2012b; Park, Chun, Oh, Kim, & Chon, 2010), increases the incidence rates of hip and knee arthritis (Kerrigan, Riley, Nieto, & Della Croce, 2000; Kerrigan et al., 2005; Simonsen et al., 2012) and has a direct and substantial influence on the ankle and foot (Cronin, 2014).

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The subtalar joint is the core structure in the biomechanics of the hindfoot, and stabilizes the foot and coordinates ankle movements. Approximately 10–20% patients with subtalar joint instability have chronic ankle instability (Harper, 1999). Subtalar joint mobility is important for foot inversion and eversion. Most of the inversion–eversion of the foot occurs at the talonavicular joint part of the clinical subtalar joint, which is associated with ankle movement only during vigorous activity. The simultaneous motions of the ankle and subtalar joints provide space for the regulation of the coronal motion of the hindfoot to absorb oscillations and attenuate ground reaction forces (Goto, Moritomo, Itohara, Watanabe, & Sugamoto, 2009). Long-term walking in high-heeled shoes damages the ankle function by increasing stress around the ankle (Kerrigan et al., 2000). Although the influence of high-heeled shoes on the ankle, the function of which is complementary to that of the subtalar joint, has already been studied (Kerrigan et al., 2000; Kim, Lim, & Yoon, 2013), the effects of wearing high-heeled shoes on the subtalar joint require further investigation.

The most substantial impact of high-heeled footwear on the foot is the change in the level and distribution pattern of plantar pressure (Zhang & Li, 2014). High-heeled shoes lift up the heel, which moves the center of plantar pressure forward and redistributes plantar pressure. Therefore, the stress to the hindfoot is reduced, while the stress to the forefoot, especially the pressure over the medial longitudinal arch and forefoot latitudinal arch, is substantially increased. The increased pressure induces arch fatigue and even injury of the plantar fascia and ligaments, which further causes foot diseases, including flatfoot and plantar fasciitis (Healey & Chen, 2010; Ko et al., 2009). By evaluating the changes in plantar pressure associated with different heel heights, Cernekova and Hlavacek (2008) found that the peak pressure under the first metatarsophalangeal joint increased with increasing heel height (Cernekova & Hlavacek, 2008). A study by Ko and colleagues (Ko et al., 2009) revealed that the pressure under the second metatarsal head increased moderately on increasing the heel height from 2 cm to 4 cm. The wearing of high-heeled shoes also has an important influence on gait (Esenyel, Walsh, Walden, & Gitter, 2003). Walking in high-heeled shoes results in shorter step length, lower step frequency and longer double support phase and forefoot loading compared with barefoot walking (Arnadottir & Mercer, 2000; Cronin, Barrett, & Carty, 2012; Gerber et al., 2012). Thus far, most studies have focused on the effects of heel height on the distribution of plantar pressure and gait; however, whether the duration of the use of high-heeled shoes influences plantar pressure distribution and gait remains unknown. Therefore, in this study, we measured plantar pressure in habitual wearers of high-heeled shoes to determine the effects of the duration of the use of high-heeled shoes on the subtalar joint, plantar pressure and gait. Our findings will provide evidence for the prevention and treatment of conditions related to the use of high-heeled shoes.

2. Materials and methods

All subjects were selected by systematic sampling. Numbers were assigned to female staff from three banks in Shenzhen (Shenzhen Development Bank, Bank of China – Shenzhen branch and China Merchants Bank – Shenzhen branch), After a power calculation, 120 were selected by fixed-interval sampling and then surveyed using a questionnaire. All subjects had no history of lower extremity injuries in the preceding year and had normal arches based on the assessment of the pressure footprint. Moreover, 20 healthy volunteers who had normal arches based on the assessment of the pressure footprint (Cavanagh & Rodgers, 1987) were included as a control group. All enrolled subjects with normal gait who had no history of musculoskeletal disease and injury in the lower limbs. The questionnaire included items pertaining to general information (age, height, weight and body mass index) and footwear characteristics (heel height, footwear type and the frequency of wearing high heels). According to the duration of the use of high-heeled shoes (as specified in the questionnaire), the subjects were divided into a control group, <2 years group, 2–5 years group, 6–10 years group, 11–20 years group and more than 20 years group. After completing the questionnaire, dynamic plantar pressure measurements were performed on all subjects.

The dynamic plantar pressure measurement was carried out using the Footscan USB plantar pressure plate system produced by RSscan International (De Weven 7, 3583 Paal, Belgium). The frequency was 400 Hz, and the sensors were 2.2 mm thick, with a density of four sensors per square centimeter. The conductor was 1.5 mm thick. The instrument measured pressures ranging between 1 and 60 N/cm^2 with the highest resolution of 25 g and consistency of ±25 g. The Footscan pressure plate was placed on flat ground, and walkways were paved on both sides of the plate. Each participant walked on the walkway at 1.30 m/s (Yung-Hui & Wei-Hsien, 2005) to familiarize themselves with the walkway before data collection. Then each subject walked on the plate in 1.30 m/s at least 3 times without shoes and socks, in order to allow the system to obtain complete plantar pressure–distribution maps for both feet. The data were analyzed using Footscan software7.0. The software automatically divided the foot into 10 masked zones (Fig. 1): the first toe (T1), the second to fifth toe (T2–5), the first metatarsus (M1), the second metatarsus (M2), the third metatarsus (M3), the fourth metatarsus (M4), the fifth metatarsus (M5), the midfoot (MF), the medial heel (MH) and the lateral heel (LH). Perpendicular to the foot axis, the foot, excluding the toes, was divided in three equal lengths: forefoot area, midfoot area and heel area (Zhang & Li, 2014). According to the Footscan software, the stance phase can be divided into four phases: the initial contact phase (ICP), the forefoot contact phase (FFCP), the foot flat phase (FFP), and the forefoot push off phase (FFPOP). The step and subtalar angles were also calculated by Footscan software after the measurement (Rusu et al., 2014).

All data were processed using SPSS 13.0 software. The descriptive data in the questionnaire survey and plantar measurements were expressed as means ± standard deviation. For the speculative data in the questionnaire survey and plantar measurements, homogeneity of variance was analyzed using the Levene test. If the variances were homogeneous, the data were