The Effects of High-Heeled Shoes: A Practical Review

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Abstract: High-heeled shoes are a prevalent form of fashionable footwear. Historically, physicians have decried these shoes’ use due to the unnatural effects on posture they produce. While most historical views regarding these shoes were based upon clinical observation, significant progress has been made in accurately characterizing many of the biomechanical and postural effects of this style of shoe. The purpose of this article is to present a practical review of the postural and dynamic gait changes patients experience when wearing high-heeled shoes.

Key words: Shoes, high-heeled, high heel, stiletto, platform, wedge, pump

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High-heeled shoes have been worn as fashionable footwear in Western society since the 17th century. Since that time, the prevalence of this shoe type has waxed and waned on account of various influences. Although previously worn by both men and women, high heels are contemporarily worn almost exclusively by women. Physicians have advised of the ill-effects this type of footwear has on comfort and function for over two hundred years, yet a high proportion of women (37-69%) continue to wear high-heeled shoes daily.

A number of reasons are suspected to account for women's persistent use of high-heeled shoes. One motivation is occupational. Women increasingly entered the sales workforce toward the end of the 19th century and were encouraged by their employers to wear high-heeled footwear. Even now, high heels remain an official dress code requirement for some workers, such as flight attendants. In the United States, the early 20th century saw a new focus on the legs and feet of women. High heels continued to become more prevalent socially due to French influence. Once established as a social norm for females, implicit social compliance became and remains an additional motivation for the shoe style’s use. Frequent media portrayal and celebrity influences are thought to have contributed to this expectation.

There are a number of psychosexual benefits that high heels afford women, and these are also suspected to further perpetuate the fashion. Wearing high heels, for example, has been demonstrated to improve women's self-evaluation of their own attractiveness, increase women's perceived attractiveness to both men and women, increase the likelihood of helping behavior from males, and decrease the likelihood of being mistaken for a man in silhouette.

Regardless of the reason for wearing them, high heels are associated with a number of effects on human
static and dynamic biomechanics. The purpose of this article is to present a practical review of the postural and dynamic gait effects patients experience when wearing high-heeled shoes.

Foot

Pressure under the metatarsal heads during walking increases with increasing heel height. The distribution of this pressure has been found to shift medially in high heels, with more weight borne at the hallux, first metatarsal, and central metatarsals. Interestingly, Snow et al. found that increasing heel height diminished, but did not eliminate, the medial shift of the forefoot pressures up to a heel height of 8.26 cm. The rate at which pressure is loaded at the metatarsals in stance is also increased under high-heeled conditions. Force at the heel during stance is decreased with high heels.

Arch height is increased, and length of the foot decreased in the high-heeled shoe condition. Also, hindfoot pronation is limited upon ground contact due to fixed ankle plantarflexion. It is suspected that the normal subtalar joint range of motion, and thus ability to absorb shock upon impact, is impaired in this footwear. Some painful foot conditions associated with high-heeled shoe use include hallux abductovalgus deformity, metatarsalgia, painful hyperkeratoses, plantar fasciitis, and Haglund’s deformity, but the association of some of these with heel height has not been isolated from other characteristics commonly found in this shoe type, such as narrow toe boxes, little padding, and lack of arch support.

Ankle and Lower Leg

In high-heeled gait, the ankle exhibits increased plantarflexion and decreased range of motion. Peak plantarflexion torque at the ankle joint is decreased in high heels. The reduced torque results from the fixed plantarflexed orientation of the foot which, although reducing the plantarflexory moment arm of the Achilles tendon, most importantly decreases the moment arm of the dorsiﬂexory vertical ground reactive force about the ankle joint axis. The plantarflexed position of the foot throughout stance also limits the available range of internal rotation for the tibia.

Under normal conditions, the center of the ankle axis of rotation in the coronal plane has been demonstrated to lie medial to the heel’s point of contact with the ground for most of stance phase. In the study by Barkema et al., this axis is elegantly demonstrated to shift from a predominately medial position at a 1 cm heel height to a predominately lateral position at 5 cm and 9 cm heel heights, causing the external forces acting upon the ankle to transition from predominately inverting to predominately eversion in nature. The intrinsic moment required to counteract these external forces concomitantly transitions from an intrinsic inversion moment under normal conditions to an intrinsic eversion moment with high heels (which increases with increasing heel height). Consistent with requisite intrinsic eversion with high-heeled gait, studies have demonstrated increased peroneus longus activity with high heels via electromyography (EMG). There is agreement among many authors that coronal plane changes at the ankle with increasing heel height biomechanically predispose patients to lateral ankle sprains.

Additional changes also occur in the musculature of the lower leg during high-heeled ambulation and after chronic use of the shoes. During high-heeled gait, studies demonstrate increased activation of the tibialis anterior, medial gastrocnemius, and soleus muscles, although there is some difference between the studies as to when the increased activation is. Some studies demonstrate increased activation of the tibialis anterior, medial gastrocnemius, and soleus muscles, although there is some difference between the studies as to when the increased activation is. Some studies demonstrate increased activation of the tibialis anterior, medial gastrocnemius, and soleus muscles, although there is some difference between the studies as to when the increased activation is.
barefoot) gait among habitual wearers of high heels, which is not reproduced in the control group. Present evidence, however, ultimately associates the chronic use of high heels with some structural and neuromuscular changes in the posterior crural musculature.

A further biomechanical influence which has provided some controversy is the relationship between high heels and the venous pump of the calf. Using air plethysmography (APG), Potério-Filho et al. compared the variation in calf cuff pressure with standing, static ankle flexion and extension, barefoot ambulation, and high-heeled (7cm) ambulation among 10 females. They concluded that ambulation in high-heels optimized the calf muscle venous pump since this scenario produced the greatest variation in cuff pressure, and attributed the improvement to the increased anterior and posterior crural muscle group activation as discussed above. Tedeschi Filho et al. contended that this conclusion is contrary to the “prerequisites” of an ideal calf pump set forth by Reccek, since one of the essential components for the pump’s function is unrestricted ankle motion. To investigate this, 30 females were evaluated using calf APG for venous filling index (VFI), ejection fraction (EF), and residual volume fraction (RVF) comparing toe raises barefoot and while wearing 3.5cm stiletto, 7cm stiletto, and 7cm platform high-heeled shoes using a carefully standardized procedural protocol. EF was significantly higher in the barefoot and 3.5cm stiletto groups compared to the 7cm shoes and RVF was significantly lower in the barefoot group compared to all others, both findings consistent with improved calf venous pump function with less heel height (VFI exhibited no difference between the groups). Of the two studies, the latter may be the more reliable given its design.

**Knee and Thigh**

The knee must compensate for the plantarflexed position and decreased range of motion of the ankle in high-heeled gait. Total range of motion of the knee during stance phase increases to compensate for reduced ankle joint compliance. Maximum knee flexion increases with increasing heel height to compensate for the decreased available ankle dorsiflexion during stance phase, allowing forward motion over the foot. During swing phase, flexion at the knee is reduced. Given the increased flexion of the knee in stance, an increased net knee extensor moment is present to maintain upright posture. While the duration of knee extensor moment is consistently found to be increased during midstance, the peak stance extensor moment is not always elevated and appears to be related both to walking speed and height of the heel. Activation of the quadriceps functions to effect the increased intrinsic extensor moment upon the knee, which has been verified experimentally by increased rectus femoris peak and mean amplitudes via EMG in the speed-controlled study by Simonsen et al. The increased tension at the patellar tendon and increased patellofemoral compression is thought to contribute to the development of patellofemoral osteoarthritis.

In the coronal plane, an increased varus moment on the knee is consistently present due to high-heeled shoes’ resultant medial shift of the body weight relative to the foot. In swing phase, there is a small decrease in hip flexion with high heels. Barkema et al. found a 10% increase in the hip abduction moment with 9cm high heels compared with heel heights of 5cm and 1cm. Simonsen et al. similarly found an increased hip abduction moment in midstance without any associated position change, whereas studies by Esenyel et al. and Kerrigan et al. did not find any statistically significant changes to the hip in the frontal plane.

**Spine and Pelvis**

In younger women, Mika et al. found the pelvic range of motion in the sagittal plane to be increased when wearing high heels without this effect in middle-aged women. Another study found posterior pelvic tilt with high-heeled gait in 13-20 year old girls compared with anterior pelvic tilt in girls who were experienced wearers. A recent dynamic study comparing high-heeled with barefoot gait by Baaklini et al. showed no significant differences between inexperienced and experienced wearers and demonstrated increased pelvic range of motion in the high-heeled state. Another static study examining full body standing
Increased lumbar lordosis was historically believed to result from high-heeled posture. According to a thorough contemporary review, however, the majority of studies have demonstrated that lumbar lordosis is either decreased or unchanged in patients’ shoe with high-heeled shoes. After its publication, a static radiographic study from China found that lumbar lordosis increased with heel height, followed by Baakens et al. again finding decreased lumbar lordosis with dynamic high-heeled gait. In the same study of girls aged 13-20 years mentioned prior, experienced wearers of high heels did exhibit increased lumbar lordosis, in contrast to inexperienced wearers whose lumbar lordosis decreased, but this finding is the exception rather than the rule. To summarize, there is significant variability between studies regarding lumbar lordosis in high heels, but most would probably agree that increased lumbar lordosis is not a common effect.

While increased lumbar lordosis is unlikely to account for the lumbago that was previously attributed to it, changes in the paraspinal musculature due to high heels are more probable to blame for some of the discomfort these shoe wearers experience. Multiple studies have demonstrated increased EMG activity in the erector spinae muscles in patients wearing high heels. Furthermore, cervical paraspinal muscle activation is increased at heel-strike and toe-off in high-heeled gait and may present another potential source of discomfort.

**General Properties of Gait**

Walking in high heels is associated with decreased stride length. Patient-selected walking velocity decreases in high-heeled gait. Cadence remains unchanged with increasing heel height in most studies. The body’s center of mass is shifted anteriorly and superiorly when shod with high-heeled footwear. As discussed in the lower leg, thigh, and paraspinal musculature, high-heeled gait is associated with increased muscle activation. Additionally, more energy is expended due to braking forces in high-heeled gait since ground reactive forces are increased in all three planes with increasing heel height. As a result, the energy cost of locomotion is increased in all three planes with increasing heel height.

**Conclusion**

High-heeled shoes are an established form of fashionable footwear in Western countries. Although popular, they produce significant alterations to normal biomechanics and some potential adverse effects may result. While avoiding this shoe type entirely may be ideal, 42% of women continue to wear them despite pain due to their aesthetic properties. Patients should be advised of the changes imposed by this type of footwear and encouraged to at least limit the frequency, duration of wear, and heel height as much as possible.

**References**


