

# High-heeled shoes and foot pain. Negative impact on plantar pressure changes

*Wysokie obcasy powodem bólu stóp.*

*Negatywny wpływ zmiany nacisku na podeszwę*

## INTRODUCTION

Undoubtedly shoes became the integral part of our everyday life. First shoes emerged in ancient times to protect feet from outside effects. Around year 1500, heels were used by the soldiers to secure their feet in stirrups while horse riding. After high-heeled shoes had been brought to

Europe by Persian migrants, they became a craze among male aristocrats. For the first time women were seen to wear high heels around year 1533 at the wedding of Catherine de'Medici and Duke of Orleans. Since then, they have appeared in females' wardrobes for good [1].

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» 348

## ABSTRACT

*The human foot is a strong, complex structure and comes into contact with the ground when walking. Its major function is to absorb the energy generated at initial contact with the ground, as well as to give it away and use it for effective movement. For hundreds of years shoes have been worn to protect feet against any injuries resulting from walking on rough terrain. High-heeled shoes have a history dating back to the 16th century and since then they have become the significant element of every wardrobe. Nowadays, high heels are inseparable element of a business dress code for women.*

*The aim of this study was to examine high-heeled shoes and their impact on the pressure in human sole together with related effects. The authors, based on the literature review, presented consequences and changes in sole pressure resulting from heels height.*

*The human heel, placed in upper position leads to restricted range of ankle motion, slower walking and its poor performance what is more, it also leads to numerous foot deformities such as osteoarticular deformities, hallux valgus, Morton's neuroma, other pain including lower back pain. High heels are also a direct cause of popular conditions characterized by heel pain, i.e. plantar fasciitis and heel spurs.*

## STRESZCZENIE

Ludzka stopa to silna i złożona struktura. Jest stworzona do absorbowania energii kontaktu z podłożem, a także do jej oddawania i wykorzystywania do efektywnego ruchu. Niezmiennie od setek lat chroni ją obuwie, które zabezpiecza ją przed ostrym podłożem. Buty na obcasach swą historią sięgają XVI wieku i od tamtej pory na stałe zagościły w garderobach zarówno kobiet, jak i mężczyzn. W dzisiejszych czasach wysokie obcasy są nieodłącznym elementem biznesowego ubioru kobiet.

Celem pracy było przedstawienie wpływu chodzenia w butach na obcasie na ciśnienie wywierane na podeszwę stopy oraz związane z tym skutki. Autorzy na podstawie przeglądu literatury wykazali znaczące zmiany ciśnienia w obrębie podeszwy stopy uzależnione od wysokości obcasa.

Podniesienie pozycji pięty niesie za sobą, między innymi, zmniejszenie zakresu ruchu stawu skokowego, zmniejszenie szybkości chodu, a co za tym idzie także jego wydajności. Prowadzi to również do powstawania licznych deformacji i sytuacji bólowych, takich jak deformacje kostno-stawowe, koślawość palucha, nerwiak Mortona, czy problemów powiązanych – na przykład bólu dolnej części pleców. Wysokie obcasy są również bezpośrednią przyczyną popularnych schorzeń charakteryzujących się bólem pięty – zapalenia rozciągnięta podeszwowego oraz ostrogi piętowej.

**Keywords:** high heels, plantar pressure, plantar, pain

**Słowa kluczowe:** buty na wysokim obcasie, obciążenie stopy, podeszwa, ból

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High heels are the prime symbol of femininity. At a very early age, girls put mothers' high heels and try to walk and there is nothing surprising in this. It is commonly known that high-heeled shoes not only make women taller, but also more slender and sexy. What is more, women in high heels increase their attractiveness to men [2]. In addition, high heels are essential part of women's business dress code and according to statistics, 60% of women office workers wear them [3]. Brand, price, trendy design – all of these factors influence our choice of shoes. Apart from a few positive aspects of high-heeled shoes, unfortunately, after all they make legs and feet swollen and painful [3].

Women wearing heels may carry an increased risk for the musculoskeletal system overload [4]. High heels cause adverse changes in the feet tissues and affect the deterioration of gait ergonomics. They can adversely affect the entire human body, starting from the toes and ending in the cervical spine [5, 6]. They are a direct cause of structural changes and toes deformations [7].

## FOOT ANATOMY AND FUNCTION

Complex mechanical system of a foot provides two important functions: weight bearing and conforming to the surface on which we walk, run or jump. Numerous joints in the foot provide high flexibility and stability what is a result of joints articulation [8]. The foot has the ability to be rigid or flexible during a normal gait cycle, at the same time providing foot stability [9]. The foot contains 26 bones, 33 joints, and more than a hundred tendons, muscles and ligaments that work together to bear weight, transmit force and allow for efficient movement. The foot is subdivided into the hindfoot, midfoot, and forefoot. The hindfoot contains two bones: the talus and the calcaneus. The midfoot consists of five irregular bones: the navicular, medial cuneiform, middle cuneiform, lateral cuneiform, and the cuboid. Connection between the midfoot and hindfoot is called mid-tarsal joint or Chopart's joint. The forefoot includes five metatarsals and respective phalanges. Phalanges are divided into proximal, middle and distal phalanx. Only the big toe contains a proximal and distal phalanx.

The muscles of the foot can be split into two functional muscle groups: extrinsic and intrinsic. The first ones are located in anterior, posterior and lateral compartments of the leg and connect to the foot. These muscles are responsible for plantar and dorsiflexion, foot eversion and inversion, as well as toe flexion and extension [10]. The second ones are found within the foot and control the proper motor actions of the foot, particularly the toes. The strongest tendon in the human body – Achilles tendon – is formed by the soleus muscle with the conjoined tendon of the gastrocnemius muscles. The plantar tendon is a continuation of the Achilles tendon, and both structures are attached to the posterior calcaneus [11]. The Achilles tendon plays very

important role in plantar flexion of the foot, so in case of increased tension of the Achilles tendon, tendon overload can occur, which usually results in plantar fasciitis [12].

The foot is composed of longitudinal (medial and lateral) and transverse arches [13]. Loads, tension of muscles, ligaments and joint capsules determine the foot arches [14]. Human walk cycle has two main phases: stance (60% of the gait cycle) and swing (40% of the gait cycle). Stance phase begins with the heel strike - this is the moment when the heel touches the ground, but the toes has not touched the ground yet. In the midstance phase, the foot settles at the lateral border. During the movement from mid-stance to toe-off stance, the 5 metatarsophalangeal joints contract. The toe-off phase is also called the propulsive phase [15]. Swing phase begins, right after the stance phase ends and is the phase between the toe-off and the heel strike phase. Whereas in the swing-phase the two extra can be recognised - acceleration and deceleration [13]. The acceleration phase goes from toe-off to midswing, while deceleration goes from midswing to heel strike. In the acceleration phase, the swing leg makes an accelerated movement to put the bodyweight forward. The deceleration phase brakes the velocity of body moving forward in order to place the foot stable on the ground. Between these two phases, the mid-swing phase occurs, where both feet contact the ground and both heels are next to each other [16]. Optimal plantar pressure is provided by well-balanced support points of the foot: calcaneal tuberosity, the head of the first and fifth metatarsal bones.

The plantar fascia is a connective tissue that supports the arch of the foot. It is subdivided into a thick central, medial and lateral components. It attaches proximally to the medial tubercle of the calcaneus. Extending distally, it divides into five digital bands that connect to the base of the periosteum of the proximal phalanx of each toe and the metatarsal heads. Plantar fascia fibres are also blended with the dermis, the flexor sheath and the transverse metatarsal ligament. Functionally, the plantar fascia provides a windlass effect on the sole and helps to maintain the longitudinal arch. J.H. Hicks proved that the plantar fascia is tensioned during the latter weight bearing stage and as the metatarsophalangeal joints dorsiflex, this applies a traction force at the point of insertion on the calcaneus [17]. He named this the windlass effect, which plays a dynamic role during the gait cycle where it elongates during the stance phase, storing potential energy during the process and locks the midfoot during toe-off to provide a rigid structure for propulsion. Then plantar fascia passively contracts, converting the previously stored potential energy into kinetic energy aiding acceleration.

## NEGATIVE EFFECTS OF WEARING HIGH-HEELED SHOES

Wearing high heels alters the neuromechanics of human movement. From the biomechanical point of view, higher heel position while walking, significantly decreases ankle movement range (ROM), changes body's mass centre and profoundly changes centre of pressure. It also reduces walking speed and increases duration of stance phase with shifted ground reaction force. It also leads to numerous deformities such as: osteoarticular deformities, hallux valgus, Morton's neuroma, as well as pain [18-20]. Moreover, habitual use of high heels can cause many problems with the low back pain as a result of postural changes like a compensatory increase in lumbar lordosis and pelvic tilt [21].

Low back pain affects nearly 60-80% of people throughout their lifetime and is one of the most common reasons for visiting a physiotherapist [22]. Pathological changes may also occur in the right medial femoral condyle in the knee joint and Achilles tendon manifested by slight thickening. These changes might be interpreted as early musculoskeletal alterations, leading to chronic overload [23]. Current studies show that the long-term use of high-heeled shoes may change the plantar pressure distribution pattern and result in morphological changes in the midfoot, moreover, increase risk of calcaneal spur and soft tissue damage, like plantar fasciitis [5, 6, 23-26].

Plantar fasciitis also called plantar heel pain is a condition that can be best referred to as "plantar fasciosis", because histological analysis demonstrates plantar fascia fibrosis, collagen cell death, vascular hyperplasia, random and disorganized collagen, and avascular zones [27]. Females diagnosed with plantar heel, slightly more commonly than males, occur more frequently in an athletic population such as runners, constituting up to 8-10% of all running related injuries. In the US alone, estimations show that this disorder generates up to 2 million patient visits per year, and account for 1% of all visits to orthopaedic clinics. Plantar heel pain is the most common foot condition treated in physical therapy clinics and constitutes up to 40% of all the patients being seen in podiatric clinics [28, 29].

Calcaneal spur can be located at the back of the heel or under the sole. The dorsal spurs are often associated with Achilles tendinopathy, while spurs under the sole are associated with plantar fasciitis. The apex of the spur lies either within the origin of the plantar fascia (on the medial tubercle of the calcaneus) or superior to it (in the origin of the flexor digitorum brevis muscle). The relationship between spur formation, the medial tubercle of the calcaneus and intrinsic heel musculature results in a constant pulling effect on the plantar fascia causing an inflammatory response [30]. The etiology of spurs has been a subject of discussions. Current reasoning is that abnormal biomechanics (excessive or abnormal pronation) is the prime etiological factor for

a painful plantar heel and inferior calcaneal spur. The spur is thought to be a result of the biomechanical fault and an incidental finding when associated with a painful plantar heel. The most common etiology is thought to be abnormal pronation which results in high tension forces within the structures that attach the calcaneal tuberosity. Asymptomatic heel spurs are relatively common among adults.

## HIGH-HEELED SHOES AND THEIR IMPACT ON PLANTAR PRESSURE

After deep analysis of the scientific research, it can be concluded that wearing high heels lead to significant changes in forefoot plantar pressure.

Shang J. et al. (2020) investigated the influences of high heels on plantar pressure among 20 adult females. Participants were walking on a treadmill and they were wearing two heel types (thin and thick) and three different heel heights (low: 3 cm, medium: 6 cm, and high: 8.2 cm). On the contrary, the control group was wearing flat shoes (heel height: 0.2 cm). Results of this examination revealed important differences in the plantar pressure distribution associated with heel height and heel type where there was an increased pressure in the first metatarsal and central forefoot region and decreased pressure in the midfoot and heel sections, thus increasing anterior shift [6].

Yin C.M. et al. (2016) examined the impact of long-term high heels use on plantar pressure changes. In this examination, the subjects (120 females) 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). The authors took into account impulse and pressure and duration peak pressure in different plantar regions which were measured with the Footscan pressure plate. The pressure under the second metatarsus showed significant differences among the groups. They proved that the heel height increases the impact force, medial forefoot pressure and perceptible discomfort during walking. In 2-5 year group smaller midfoot contact areas for both feet and higher subtalar joint mobility were noticed, while the 6-10 year group had larger midfoot contact areas for both feet and prolonged foot flat phase during gait. Moreover, the collapse of the latitudinal arch transferred the forefoot load to the second metatarsal head, which increased the pressure under the second metatarsal head. The researchers emphasize that the mechanisms showing the impact of the duration of wearing high-heeled shoes on forefoot latitudinal arch, still require further study [26].

Yung-Hui L. and Wei-Hsien H. (2005) conducted research on improving the comfort during walking in high heels by decreasing negative high plantar pressure in the forefoot by applying the shoe inserts. Ten participants volunteered for this study. Four subjects were using high-heeled shoes two-to-five times per week for at least 1 year. The other six

had relatively limited experience. The results of this study showed that shoe inserts use reduced heel pressure by 25%, medial forefoot pressure by 24%, attenuate the impact force by 33.2%, and offered higher perceptible comfort comparing to the non-insert group [24].

## CONCLUSIONS

Many scientific studies prove that high-heeled shoes are not the best option. Using high heels may lead to significant differences in pressure appearing in the sole what afterwards may lead to osteoarticular changes, hallux valgus, Morton's neuroma or more common conditions such as plantar fasciitis and heel spur, but only long-term wearing high-heeled shoes for many years can increase the risk of lesions mentioned in this paper. Walking in high heels significantly reduces speed and efficiency of human movement, and what is more, can even cause low back pain. It is worth to mention of the consequences of wearing high-heeled shoes and by introducing appropriate prevention try to minimize the negative consequences.

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