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High heels and evolution

Natural selection, sexual selection and high heels

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Abstract

Application of Darwinian evolutionary theory to the behavior of modern humans is a challenging but important enterprise. Evolutionary theory has the potential to illuminate aspects of human behavior that have previously been treated only in an atheoretical or descriptive manner. Strict Darwinian theory is based on the principle that individuals behave in a way that is in their own best genetic self-interest. Clearly, humans engage in a wide variety of behaviors that on the surface seem to run counter to basic evolutionary principles, and these behaviors range from bungee jumping to smoking. Certain aspects of fashion seem to also fall into this paradoxical behavioral category. Wearing high heels is a widespread behavior pattern among Western women and seems to persist in the population in spite of its potentially fitness-decreasing attributes. Many will argue that traits that are as culturally variable and labile as fashion could not have any underlying genetic basis. While culturally variable tastes in fashion are unlikely to come under direct genetic control, they may reflect some basic human adaptations associated with mate attraction. While it is unlikely that there is a gene for wearing high heels, the tendency to wear high heels under certain social conditions may be a manifestation of a larger pattern of behavior associated with mate attraction. While imposing costs on the wearer, many women still wear high heels. An evolutionary perspective on this behavior provides an alternative to more social constructionist explanations.

Keywords: Darwinian evolutionary theory, natural selection, fashion

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> The cavalier treatment to which the human race has subjected its feet for the last thousand years following the dictates of fashion, does not make one suppose that an era of non-deforming shoes is in sight. Instead one awaits with a grimace of anticipatory pain the next great leap forward of the high priests of fashion.
>
> (Cameron 1978: 859)

Introduction

What do Miss America, Barbie, the Rockettes, Ginger Rogers, Naomi Campbell, and millions of other women have in common? They routinely engage in a risky behavior that in some ways defies common sense – wearing high-heeled shoes. Nonetheless, this behavior is pervasive in Western society and increasingly seen in developing countries as a marker of social status (Freeman 1999; Miller 1990).

From an anthropological perspective wearing high heels is an interesting example of the curious ways culture and biology sometimes interact. When our basic biological tendencies interact with culturally based traits they can do so in at least two entirely different ways. First, the biological tendency or predisposition can act in a way that appears consistent with the cultural trait. The cultural trait prescribes that we behave in a particular manner and our biological predisposition reinforces that behavior. For example, it is widely accepted that one should act in a supportive manner toward kin. We tend to act in this way in no small part because our basic biology reinforces this behavior. It makes good evolutionary sense. Culture and biology are running parallel to each other headed in the same direction; they are mutually reinforcing the same types of behavior. On the other hand, there are instances when a cultural trait and underlying biological tendencies appear to run counter to each other. In this case both internal and external conflict are likely. Individuals may feel inclined toward certain types of behavior as a result of evolved psychological predispositions, while the surrounding culture may reinforce behaviors that may be in total opposition to that predisposition. The conflict surrounding these behaviors that run counter to our evolved predispositions is particularly interesting. When culture dictates a practice that is manifestly dangerous or risky, and runs counter to general concerns of survivorship and reproduction, but nonetheless persists in the population, then it is worthy of careful attention. One is compelled to ask how such an apparently maladaptive behavior can persist.

It can be argued that wearing high heels is a behavior that is consistent with human concerns about attracting opposite-sexed mating partners and is a reflection of our evolutionary past in which selection played an important role. Specifically, Darwin recognized a process that may or may not be consistent with trends in natural selection which he called sexual selection. Take, for example, the elaborate plumage and courting display of the common peacock (*Pavo cristatus*). His flamboyant feathers are adorned with blue and green eyes (ocelli) and he spreads and quivers his tail in an elaborate display in order to attract the interest of peahens. The tail feathers (100–150 in number) may grow as long as five feet (Mannucci and Minelli 1993) and it has been demonstrated that the larger the train of feathers the greater the mating success of the males (Petrie, Cotgreave, and Stewart 1996). This is significant because it highlights the importance of advertising in mate choice. Also of note is the cost of the plumage to individual peacocks. The long elaborate train clearly imposes some significant costs (in terms of reduced flying ability) on the possessor. Nonetheless, the trait is maintained in the population. Now both the advertising signal and its cost become relevant in mating decisions.

Sexual selection as an evolutionary process is composed of two aspects. First, organisms must compete with others of the same sex for access to the most attractive mating partner, or in some cases for any mating partners at all. And second, members of one sex will select partners from the competing sex. We typically think of these two types of behaviors as male–male competition and female choice. While this characterization holds true for many animal and bird species, humans are a bit different in that both sexes engage in both competition and choice. Males as well as females engage in both competition among members of the same sex, and simultaneously exhibit choice of members of the opposite sex. Therefore, in the case of wearing high heels, women are competing with other women for the attention of males from whom they will select the most suitable partner.

The purpose of this paper is to examine this widespread cultural practice of wearing high heels from an evolutionary perspective. Alternatively, wearing high heels might be interpreted as a cultural trait following no particular underlying evolutionary predisposition, but reflecting cultural ascription of gender and status. Wearing high heels could be a type of culturally defined gender marking of the inferior status of women in a patriarchal society. Furthermore, one could argue that high heels are simply a way of physically as well as symbolically controlling the reproductive status of women.

It is clear that there are a variety of theoretical paradigms that could be used to explain and interpret wearing high heels (feminist, deconstructionist, symbolic, psychoanalytic, etc.), but one largely overlooked perspective is derived from evolutionary theory. It is possible that wearing high heels has basic, fundamentally fitness-enhancing aspects that offset the high costs associated with the practice. This paper views wearing high heels as a cultural practice that has a historical basis that may very well be

different from the function it seems to serve in modern society, and argues that such cultural practices may have evolved in concert with some basic biologically patterned behaviors.

A reconstruction of the historical basis for wearing high heels is not attempted, except in the most general terms in order to illustrate the possibility that wearing high heels might have some evolutionary implications. In order to develop an evolutionary perspective one must assess the costs and benefits of a particular behavior or practice in its ecological/environmental setting in order to understand its effects on fitness (reproductive success or genetic representation in future generations (Beatty 1992)). The costs of wearing high heels are enumerated in this paper in some detail for they are often a poorly considered aspect of this cultural practice. Given that it is quite costly to wear high heels, one is faced with the identification of benefits that outweigh these costs. The offsetting benefits associated with wearing high heels are fitness-enhancing properties enjoyed by the wearer. These fitness-enhancing properties are directly related to interaction of cultural practices and sexual selection.

Flamboyant displays are well documented among animals, and it is generally thought that these displays are often implicated in patterns of reproduction. Darwin recognized that both males and females of various species have evolved all sorts of contrivances to attract the interest of the opposite sex, ranging from brightly colored plumage, elaborate displays of locomotory expertise, to accumulation of non-essential decorative nesting materials. Humans are also subject to these same forces of sexual selection and have developed a considerable array of mate-attraction devices. The evolution of larger and larger brains allowed the development of culture and with it came the not only different types of ornamentation but more varied ornamentation. With the evolution of increasingly complex neurological substrates, the constraints on the types of ornamentation possible were significantly relaxed and cultural augmentation of these displays became commonplace (Low 1979, 1994). Interestingly, human displays have invaded almost all aspects of life, including some of our most basic evolutionary adaptations. On one level, it would seem that selection would not tinker with basic anatomical characteristics that are defining features of humanity, but it appears that culture has opened the way for alterations in fundamental evolved adaptations not paralleled in adaptations seen in any other animal species.

There are many interesting and sometimes paradoxical aspects of human mate selection, but one of the most interesting is the *cultural* intervention into a basic hominid *biological* adaptation: bipedal walking. Humans evolved bipedalism several million years ago, and while it is the subject of considerable study by anthropologists (e.g. Gregory 1928; Hunt 1994; Huxley 1926; Jablonski and Chaplin 1993; Le Gros Clark 1970; Morton

1926; Napier 1964, 1967; Tuttle 1981) the precise evolutionary pressures favoring this odd pattern of locomotion in humans will likely never be known. It is clear that for millions of years humans made their way around this planet walking bipedally relying only on their bare feet, and it is only within the last few thousand years of human history that any covering existed for the feet. While foot coverings are known for both males and females from the archaeological as well as the historical record, it is females who have experienced the most dramatic cultural interventions and elaborations as evident in the diverse footwear worn in Western society today, as well as in the recent past. Historically, however, men as well as women have worn high heels. Louis XIV, for example, popularized high heels among the French aristocracy. During Elizabethan times men in the royal court wore high heels, partially for decorative purposes, but also to increase their stature. Eventually, however, men gave up high heels and only women remained precariously balanced on narrow pedestals. The persistent wearing of high heels by women in modern society is a cultural practice that invites an anthropological and evolutionary analysis. Disrupting our fundamental pattern of locomotion by wearing high heels is a dramatic *step* that may have significant negative as well as positive consequences for the individual.

The inevitable question that arises is, why would anyone wear a shoe that likely results in back injury, deformation of the foot, debilitation of muscles and ligaments in the lower leg and foot, reduced mobility, increased accidental injury, pain and discomfort? From an evolutionary perspective this behavior makes no sense. Humans, like all other organisms, are generally thought to act largely in their own self-interest and not engage in self-injurious behaviors unless it makes good sense in the calculus of evolution. Given the potential negative consequences of walking in high heels, one questions the evolutionary 'common sense' of such a practice. In strictly Darwinian terms, wearing high heels is a costly enterprise and is likely not to be fitness maximizing. An explanation for such a widespread practice in Western society may rely on cultural practices acting in concert with evolved psychological tendencies favoring what are perceived to be mate-attraction strategies. Even though they are uncomfortable and debilitating, women continue to wear them. To put it somewhat crudely, do women who incur the many costs of wearing high heels enjoy compensatory benefits in mate choice and selectivity? If we possess particular behavioral predispositions it is not likely that they are directed specifically at wearing high heels, but are more general tendencies to engage in behavior that is likely to attract a mate. As such we need to view wearing high heels as consistent with a biologically evolved mating system that is heavily culturally mediated. This is an important point that should not be overlooked. It is unlikely that there exists a specific gene for wearing high

heels, but it is likely that there may be a suite of genes that predispose us to engage in any behavior that will attract mates, under a particular socioecological condition.

Evolution of bipedalism and feet

Bipedalism is a relatively uncommon form of locomotion that occurs in two distinct forms: saltatory or leaping bipedalism, and cursorial or striding bipedalism.[1] Bipedal locomotion poses a number of biomechanical challenges that have been solved in various ways by different species. Human bipedalism is a solution to the problems of biomechanics and the force of gravity that are not paralleled in any other living form. Adaptations are found not only in our feet, but the musculature of our legs, the shape of our pelvis and vertebral column, the position of our skull, the size and organization of our brain, the orientation of our reproductive organs, the structure of our internal organs, as well as our hands and arms.

There is little disagreement among paleontologists today that bipedalism and postural uprightness have a long history in the hominid fossil record; however, considerable disagreement exists over the identity of the earliest bipedal hominid, as well as the precise evolutionary pathway of bipedalism among the various types of early ancestors.[2] It is clear from the fossil record, as well as a comparative study of locomotory patterns of non-human primates, particularly the Great Apes, that the human foot is the product of selective pressures inexorably related to our peculiar method of locomotion. We stand with our backs vertical and our legs straight, unlike our primate relatives who stand with sloping backs and bent legs. For humans the center of gravity is quite high, being situated approximately two inches above the pelvis. The center of gravity for a bipedal chimpanzee, with its trunk leaning well forward, is well in front of the hip joint.

When any animal stands, its center of gravity must be directly above its feet. A human being is a very tall structure balanced on a relatively small base. Consequently a person must stand with feet directly under the hips, while a chimpanzee must keep its feet forward of its hips in order to stand bipedally (see Figure 1). For a human, erect bipedal posture is very much like standing an old-fashioned glass soft-drink bottle on its neck (Williams 1974). In normal erect posture the line of gravity passes through the external auditory meatus, anterior to the bodies of the cervical vertebrae, through the third lumbar vertebra, just posterior to or through the hip joint, just anterior to the knee joint and anterior to the lateral malleolus (Basmajian 1978).

Humans have relatively large feet in order to help maintain the vertical alignment of our body with the center of gravity. Even larger feet might make stationary posture easier; however, it is likely that they would compromise locomotion. The human foot differs from the feet of other cursorial bipedal forms (e.g. birds) in that not all of the sole of the foot touches the ground, for when we stand barefoot on a flat surface the heel and ball of the foot rest on the ground, but the arch is raised (Alexander 1992). In many Western populations the 'normal' foot is flat due to prolonged wearing of shoes in childhood. The modern human condition differs from all other primates in several important ways:

1 The hallux (big or great toe) is no longer divergent and actually projects forward beyond the other toes. The hallux is physically bound in line with the other toes by the deep transverse metatarsal ligament. The realignment of the hallux and the formation of the ball of the foot are related to the final propulsive thrust during striding provided by the terminal phalanx of the big toe (Fleagle 1992).
2 The usual transverse arch of the mammalian foot has been supplemented by the longitudinal upward curving arch between the heel of the calcaneous and the heads of the metatarsals (Okada, Ishida, and Kimura 1976). This longitudinal curve serves as an elastic bow that allows the foot to absorb the effects of vertical forces, more or less like a spring (Ker, Bennett, Bibby, Kester, and Alexander 1987; Martin 1990). Unlike our close relatives, the Great Apes, who have no arches, the human foot consists of two primary arches, the longitudinal arch (divided into a medial and lateral component) which supports our weight and absorbs the shock of walking, as well as the metatarsal or transverse arch which helps us balance when crossing uneven terrain (Scholl 1931) (see Figure 1).
3 The increased development and refinement of a heel provides an insertion point for the greatly enlarged gastrocnemius muscle as compared to other primates, and especially the Great Apes. This muscle lifts the body up and forward, causing the weight of the body to be shifted forward onto the ball of the foot, as occurs in walking and running.

Given these anatomical characteristics it is tempting to think of our feet as highly specialized organs especially when compared to the largely unmodified mammalian foot of the apes, but when compared to the highly specialized feet of deer and horses (Farish 1993) the human foot is considerably more generalized. Although generalized in some comparisons, human feet are among the most intricate structures in the human body. Feet comprise one-third of the bones in the body, each containing 26 bones, some 35 joints and more than 100 ligaments, tendons, and muscles. When we walk, our feet receive 2.5 times our body weight with each step (105–110 per minute) and when we run that pressure increases to 4–5 times. The

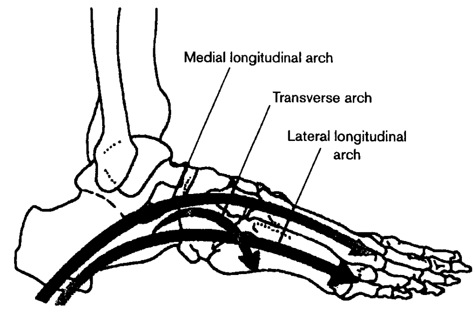

Figure 1 Lateral view of the right foot showing the major arches of the foot. Adapted from Marieb (1995)

average person walks 62,500 miles (2.5 times around the earth) during their lifetime. So of all our anatomy our feet take the greatest abuse.

Typically, feet are no more than one-third as wide as they are long. Sole pads are 0.4 to 0.8 inches thick with an emphasis on the heel. Toes are unequal in size with the great toe the longest in most individuals. If the second toe is longer it is a condition called the Grecian foot (Krantz 1992). In ancient Greece goddesses were often depicted as having a second toe that was longer than the great toe. The protruding second toe was said to give the goddess special male phallic powers. The human foot is stiff and no longer good at grasping, unlike our Great Ape relatives, although there are individuals that have developed considerable strength and flexibility in their toes as the result of birth defects in the arms (Wood-Jones 1929). In normal humans, the distal ends (tips) of the metatarsals (1–5) touch the ground while the proximal ends of the metatarsals (1–4) do not: they are elevated into the arch of the metatarsus. Only the fifth metatarsal (little toe) habitually touches the ground along its entire length at the outside of the foot.

'Man is born barefoot, and barefoot he compassed the earth. Therefore, it should be to barefoot peoples that we should turn to study the natural anatomy and physiology of the foot . . .' (Stewart 1972: 119). The anatomy and condition of the feet of people who habitually do not wear any shoes is of considerable interest, for it provides a point of comparison with the feet of modern humans living in Western society. Morton (1935) describes the feet of 147 Central African subjects as '. . . [not having] been affected by the influences of civilization, such as shoe-wearing and well-intentioned advice as to proper foot posture . . . the African series represents as nearly as it is possible to obtain, a product of pure nature' (pp. 128–9). The angle of gait shows a mild degree of out-toeing (0° to 15° for each foot) with the right foot generally showing a slightly greater angle. Common type of arch troubles do not exist among non-shoe-wearing populations (p. 172). Hypermobility of the first metatarsal has been observed in African populations and has been identified as the first degree of pronation. Individuals with such feet '. . . are quite capable and efficient; the fact that they are often observed in runners and sprinters attests to their functional capabilities' (pp. 189–90). In unshod populations feet adapt to harsh conditions. Stewart notes that the corium or dermis of unshod Bantu feet is 0.25 to 0.35 inches thick, providing ample protection from environmental insult under most circumstances. Sim-Fook and Hodgson (1958) note that in unshod Chinese populations the sole of the foot has a thick keratinized layer 0.2 to 0.4 inches thick permitting individuals to walk with no discomfort. In general, authors conclude that in unshod human populations there are relatively few deformities and pathological conditions except for infections from injuries and from parasites (e.g. *Dermatophilus penetrans, Treponema pertenus*) (Engle and Morton 1931). In general, it has long been recognized that constricting footwear was the chief source of deformities in the feet of Western populations (Barnicot and Hardy 1955; Craigmile 1953; Sim-Fook and Hodgson 1958).

History and evolution of high heels

Human feet likely evolved in a tropical, savanna-like environment unprotected from the elements. As human populations expanded into more temperate habitats, foot protection became important, largely due to increased risk of injury due to frostbite. The history of footwear and its manufacture is well studied and beyond the scope of this paper. However, a brief review of the historical basis for wearing high heels may help identify changes in patterns of wear since their introduction. Identification of these changes may be useful in understanding the main functions of high heels for women (e.g. protection, status marker).

Briefly, the sandal is the oldest foot covering known, having been traced back at least 9,000 years. In its original form the sandal was made of sagebrush bark or tules (Stewart 1972). Moccasins and boots also have some considerable antiquity while all other basic shoe styles (clog, mule, oxford, and pump) are not much more than 300 years old and all initially were designed by men for men (Seale 1995). The introduction of high heels fundamentally changed the function of shoes from one of potential protection, modesty, or expression of status to one of blatant sexuality.

Aeschylus (525–456 BC), father of Greek tragedy, created the first high heels by making shoes with a high wedge sole called korthonos. He wanted to add majesty to the heroes of his plays so that they would stand out from the lesser players and be more easily recognized. Greek women who came to the performances quickly copied the style and the fashion spread rapidly through the upper tier of Greek society. Some women carried it to extreme with cork soles that were as much as a foot high (Severn 1964). The Roman version of high heels, like the Greek, was basically a part of an actor's costume, but rapidly became adopted for wear by the wealthy as a mark of social status (Rossi 1993).

While Greek and Roman women adopted high heels early on, European women adopted high heels a bit more slowly and initially for more utilitarian reasons. European cities in the twelfth and thirteenth centuries were characterized by the lack of paved streets and by poor sanitary conditions. Initially, platform shoes were quite popular and consisted of three-inch or higher platforms that elevated the shoes and wearer above the mud and filth in the dirty streets (Rossi 1993). Women wore platform soles to keep their shoes as well as their skirts from the dirty streets (Severn 1964).

Wedge soles entered the world of fashion in fourteenth-century Europe as a graceful pedestal three-inch high with a toe band under which the wearer slipped her shoe. These pedestals increased in height to a reported maximum of approximately one foot. Gradually the pedestal and the shoe became one piece. Simultaneously with the increase in the height of shoes, skirt length was also increasing and skirts typically touched the floor. Consequently, women experienced difficulty in walking, and had to raise their skirts in order to walk (Scholl 1931).

The platform shoe reached its peak between the sixteenth and eighteenth centuries and was the forerunner of the modern high heel. A Turkish shoe pattern called the chopine, or stilt soles, was a high pedestal or hollowed cylinder made of cork with a slipper toe top to accommodate the foot. This style was widely adopted, but it was particularly favored by women of Venice in the sixteenth century, and chopines proved to be an effective method of negotiating the filthy streets without damaging the cumbersome and unwieldy farthingale (a hoop skirt of the Elizabethan period) (Brooke 1971). Since women in Venice traveled mostly by gondolas and consequently did not have to walk very far, the chopines grew taller and taller, averaging 6–18 inches, but heights up to 30 inches were reported. Chopines also had their shortcomings, for in 1430 a law was enacted in Venice that prohibited pregnant women from wearing them because of the deleterious effects on the fetus if the mother fell.

The widespread appeal of high heels is attributed to Anne of Brittany (1477–1514), Queen of France, who felt that the height of her shoes helped conceal her partial lameness (Severn 1964). But it was Catherine de Médici

(1518–89) of Florence, later queen of France, who gave the high heel its universal fashion launching. Prior to her marriage to Henry II of France, she had several pairs of high heels designed and imported from Italy to make her look taller. At the wedding and the reception her high heels were a fashion sensation and soon became a status symbol for the aristocracy such that for many years commoners were not allowed to wear them. From this exclusivity it is thought that the expression 'well-heeled' was derived (Rossi 1993). The tradition of high heels continued in France from the sixteenth to the eighteenth centuries with the Bourbon Dynasty. King Louis XIV (1638–1715), a very short man, had cork heels added to his shoes to increase his stature. All the members of his court followed his lead and did the same thing, and as a result, he lowered his heels and the shorter heel known as the Louis heel found its place in fashion (Severn 1964). Marquise de Pompadour (1721–64), mistress of Louis XV, was responsible for the first true French heel. The heels were so tall that it was difficult to walk in them and women used long walking sticks to balance themselves and adopted a cautious gait of mincing little steps just to keep from falling.

America followed the fashion trends of Europe, but it was not until 1880 that the first American high-heeled shoe was produced domestically. Prior to the domestic manufacture, women wore 'French heel' shoes imported from Paris. High heels were popularized in the 1850s largely by the clientele of a well-known New Orleans brothel, Madam Kathy's. The leggy look and mobile torso derived from wearing high heels was of considerable interest to the patrons of Madam Kathy's. She noted that her business skyrocketed when she employed a recent immigrant from France, a woman whose trademark was wearing high-heeled shoes. It was not long before the fashion trend spread through other New Orleans brothels as well as into more legitimate fashion venues. Men were ordering these French-made shoes for their wives, and in order to meet the demand the first domestic high-heeled shoe factory opened in America about 1880. Thus the high heel in America owes its success to the popularity of scantily clad prostitutes wearing 'French heel' shoes (Rossi 1993). It is generally not the case that cultural traits diffuse up the social scale, but typically the reverse is seen.

Costs of wearing high heels

Anatomical

In order to fully appreciate the costs associated with wearing high heels one must consider the effects of high heels on the anatomy of the foot. High heels are the most deforming of all shoes because the longitudinal arch of the foot is tipped up on end, and pressure is directed toward the toes, rather than distributed evenly between the toe and heel. The arch is no longer an

arch and provides no support at all. High heels convert the front end of the arch (that nearest the toes) into a supporting column, a task for which it is utterly unsuited. The idea would be excellent if we were evolving into a race of toe dancers, but that seems improbable (Estabrooks 1941) (see Figure 2).

Figure 2 Radiograph of woman's foot in a high-heel shoe. Note the dramatic transfer of weight from the hindfoot to the forefoot as a result of the extreme elevation of the hindfoot

Fractures

It is widely reported in the literature that instability while walking in heeled shoes often results in falls with hip fractures. Patients with such injuries often develop complications, including serious and sometimes fatal cases of pneumonia and pulmonary embolism. Thus it can be argued that high-heeled shoes could not only lead to injury and permanent deformation of bones in the foot, but can contribute indirectly as a cause of mortality. Empirical data on injuries arising from wearing high heels are largely lacking, although Nieto and Nahigian (1975) report on injuries suffered by individuals wearing shoes with soles ranging from 0.8 to 1.6 inches and heels measuring up to six inches. These injuries include fractures to the ankle area, displaced bimalleolar fractures, fractures of the lateral malleolus and non-displaced fractures of the calcaneous. High heels, combined with a high sole, may also contribute to a reduction in the perceptual awareness of the position of the foot, coupled with delayed kinesthetic and tactile responses to a loss of balance. In addition, they also elevate the center of gravity as much as 3.5 inches (Nieto and Nahigian 1975). The net result is an unsteady locomotory platform leading to possible injury.

Human feet account for about 10 per cent of the total surface area of the human body (200 in^2). Of that 10 per cent, less than half (only about 8 in^2) is in contact with the ground. The surface area of the unshod foot that contacts the ground is further reduced by encasing the foot in a high-heel shoe that essentially reduces the area of the foot in contact with substrate by more than 50 per cent (approximately 4 in^2) (Rossi 1947). Imagine trying to balance an object five feet high, weighing 120 pounds on two pedestals each approximately two square inches. Factor in the significantly reduced amount of heel surface area that is in contact with the ground and you can easily see the challenge presented by high heels.

The twisting action of the ankle resulting in a loss of balance is the mechanism of injury reported most frequently in cases related to wearing high heels. The resulting force was produced by either the inversion or eversion of the foot at the ankle joint. In some cases the strain may rupture the deltoid ligament and widen the mortise of the ankle (the space formed in between the talus, calcaneus, and fibula) resulting in the displacement of the talus, which strikes over the fibular area producing a fracture (Nieto and Nahigian 1975).

Hallux valgus

Hallux valgus (bunions) is a deformity of the foot characterized by lateral angulation of the great toe at the metatarsophalaneal joint. The metatarsal moves laterally while the proximal phalanx moves medially. Also associated with the displacement of the great toe is the enlargement of the medial

side of the head of the first metatarsal bone and the formation of a bony prominence that in time becomes covered by a bursal sac (see Figure 3). This often results in the appearance of a knotty projection on the medial (great toe side) of the foot and often pain and sometimes infection associated with the rupture of the bursal sac.

Besides the pain associated with bunions, an additional consequence of Hallux valgus (HV) is the increase in pressure of the forefoot during normal locomotion. Interestingly, forefoot pressures are not only elevated under the first metatarsal, but under the second and third metatarsal as well in individuals with HV (Yamamoto, Muneta, Asahina, and Furuya 1996). Snow, Williams, and Holmes (1992) found an increase in peak pressure beneath the metatarsal heads with increasing heel height. Schwartz, Heath,

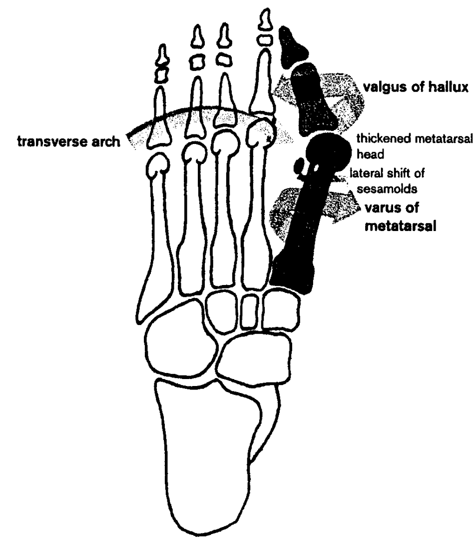

Figure 3 Hallux valgus. Note the lateral (toward the outside of the foot) rotation or valgus of the proximal (nearest the body) phalanx of the great toe with the medial (toward the inside of the foot) rotation or varus of the first metatarsal. The sesamoid bones are laterally displaced and the head of the metatarsal is thickened.

Morgan, and Towns (1964) found that a two-inch high heel was sufficient to decrease the load under the heel and increase the load on the metatarsal heads. Coughlin (1995) found that a 0.75-inch increase increased plantar foot pressure 22 per cent, a 2-inch heel increased pressure 57 per cent, and a 3.25-inch heel increased pressure 76 per cent from flat conditions. Nyska, McCabe, Linge, and Klenerman (1996) also found that high heels (2.25-inch) increased the load on the forefoot and reduced it on the hindfoot when compared to low heel (0.67-inch) shoes. For subjects with HV the intermetatarsal angle (angle between the first and second metatarsal) was also increased (Yamamoto et al. 1996). High forefoot pressure affects the great toe and has been suggested as one of the major causes of bunion deformity and metatarsalgia (a syndrome of pain in the region of the metatarsal heads) (Seale 1995). On the other hand, Bransby-Zachary, Stother, and Wilkinson (1990) found that high heels actually decreased forefoot pressure, but the increased heel height resulted in higher impact pressures. Corrigan, Moore, and Stephens (1993) found that changing heel height did not affect total load on the forefoot, but the elevation of the hindfoot decreased the forefoot contact area and increased forefoot pressure on the remaining forefoot surface area with as little as a 2 to 4 cm heel increase. Increasing heel height was also found to increase the tendency to pronate the foot.

Two explanations have emerged to explain the occurrence of HV. For a considerable time it was widely accepted that wearing pointed, short, narrow or high-heeled shoes was the cause of HV (Barnicot and Hardy 1955; Craigmile 1953; Fishbain 1925; Frean 1994; Frey, Thompson, and Smith 1995; Frey, Thompson, Smith, Sanders, and Horstman 1993; Hoffman 1905; Schmid 1994; Scholl 1931; Sim-Fook and Hodgson 1958; Soutter 1906; Stewart 1972). Alternatively, it has been suggested that fundamental defects in foot architecture often manifested early in life, and not shoe design are to blame (Dickson and Diveley 1953; Lewis 1989). According to the defective foot architecture hypothesis the maldevelopment of the first metatarsal bone, in which it fails to assume the position it should occupy, is the primary structural defect in the foot for HV. The inward divergence of the first metatarsal and the pronation (rotating inward) of the foot produces a faulty alignment of the great toe so that during walking the thrust of the great toe against the ground tends to force the toe laterally at the metatarsophalaneal joint into the HV position. Finally, depression of the longitudinal and metatarsal arches results in faulty mechanics of the great toe and tends to pull it laterally leading to the further development of HV (Dickson and Diveley 1953). In advanced cases, Dickson and Diveley (1953) note that a fluid-filled bursa develops over the prominence on the medial side (inner) of the head of the first metatarsal bone that may become infected. An infected bursa may break down leading to the development

of a fistulous opening discharging bursal fluid or purulent material. Nonetheless, the outcome from the defective foot architecture hypothesis and the high heels hypothesis is identical.

In a study of 356 women from 20–60 years of age and of various occupations (professionals, nurses, clerical, students) Frey et al. (1993) found that 54 per cent of her sample had HV. Equally astonishing was the observation that 76 per cent of the women had at least one foot deformity. This study, along with many others, suggests that HV is a condition nearly always found in shod populations. Moreover, HV is largely confined to women. In a study of foot operations over a fifteen-year period, 94 per cent of the surgical interventions for HV were conducted on women, while in the same study if was found the proportion of males and females were approximately equal (44 ♂♂ vs. 56 per cent ♀♀) for procedures involving osteoarthritis of the ankle, as well as ankle fractures (46 ♂♂ vs. 54 per cent ♀♀). Combined with the observation that the prevalence of HV increases dramatically from the fourth to the sixth decade of life in women, but not in men (Coughlin 1995; Coughlin and Thompson 1995) there is a strong suggestion that footwear plays a significant role.

High heels are implicated as a primary cause of HV based on data from unshod human populations. MacLennan (1966) found that only 2 per cent of 591 women examined in a barefoot population in New Guinea presented with HV. Similarly, Kato and Watanabe (1981) reported that archaeological evidence from as early as 6000 BC suggested that ancestral Japanese populations did not suffer from HV. Interestingly, only when the Japanese abandoned the traditional footwear (geta) for leather shoes did HV become prevalent in the population. Operations for HV were essentially unknown prior to 1972 which is the approximate date for a dramatic rise in the number of factories producing leather shoes (Kato and Watanabe 1981).

Researchers have found that when the foot is forced into a high-heeled shoe with a pointed toe and allowed to pronate from added body weight and debilitation of the intrinsic muscles, the first toe deviates in an increasingly lateral direction. The flexor and extensor tendons of the great toe, along with the sesamoid bones, exert traction upon the big toe causing further vulgus (Cailliet 1997). This explanation emphasizes a functional accommodation of the foot to debilitating shoes consistent with the high heels hypothesis, in opposition to the defective foot architecture hypothesis. If HV were fundamentally a problem in foot architecture one would hypothesize the incidence rate should parallel the demography of the population at large. It is interesting to note, however, that the ratio of women to men that have this condition is 40:1 suggesting that while deformities of the foot may play a role, it is minor when compared to the amount of deformation due to high heels.

In addition to wearing high heels, HV is further exacerbated by wearing poorly fitting shoes, a notorious problem with high heels because of the emphasis on the weight-bearing forefoot (Coughlin 1995). In a study of 255 women, Frey and her colleagues (Frey, Thompson, and Smith 1995) found that approximately 78 per cent of the subjects studied suffered from some type of foot deformity and the most common contributor was HV (approximately 71 per cent). The incidence of foot deformities was found to increase with increasing shoe size and this was interpreted by investigators to be attributable to the difficulty experienced by women with larger shoe sizes in receiving a proper shoe fit (Frey et al. 1995). Not only do high heels contribute significantly to HV, poor shoe fit seems to be a culprit as well.

Back pain and postural changes

High-heeled shoes are reported to be a major source of back pain for many women (Cailliet 1995; Franklin, Chenier, Brauninger, Cook, and Harris 1995; Homola 1968; Scholl 1931; Williams 1974). High-heel shoes cause the wearer to stand with knees and hips flexed, contributing to back problems (Soames and Evans 1987). Balance is disturbed (Williams 1974; Zohn 1988)[3] and problems with maintenance of normal muscle tone are encountered. Compensatory motion, in turn, alters tissue-stress patterns which may contribute to lower back pain (Opila-Correia 1990). Changes in the lower limbs, spine, pelvis and even jaw problems are seen in individuals who wear high heels (Sachs 1993) (see Figure 4).

One of the debated consequences of wearing high heels is alteration of standing posture, in particular, changes in lumbar curvature and the angle of inclination of the pelvis. Bendix, Sorensen, and Klausen (1984) found that lumbar lordosis as well as pelvic inclination decreased with increasing heel height (–1.0, 0, +1.75 inches). Lumbar angle and pelvis inclinations were negatively correlated and they concluded that high-heeled shoes tend to force the body to fall forward and this tendency seems overcompensated as the line of gravity comes closer to the malleolus (bony protuberance on either side of the ankle) with the high heels. This dislocation is brought about by extending the ankle joints more than just to adapt to high heels; consequently, the legs and trunk shift backward. To compensate for this reaction, the upper trunk is inclined forward, giving rise to a decrease in lumbar lordosis. Opila, Wagner, Schiowitz, and Chen (1988) found small, yet statistically significant, changes in the lumbar and pelvic structures while standing. When the trunk moved backward to counteract the sensation of falling forward induced by wearing high heels, the whole body became aligned, the lumbar curve was reduced, the pelvis rotated backward, the legs became more vertical, the hamstrings relaxed and there was a tendency toward hyperextension at the hip. Similar changes, including a statistically

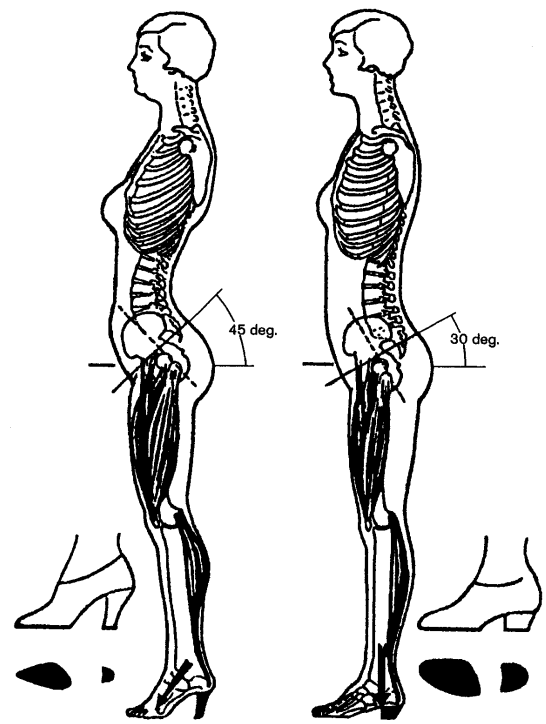

Figure 4 Effects of two heel heights on standing posture, changes in the lumbar curvature and the inclination of the pelvis. Redrawn from Rossi (1993).

significant decrease in anterior pelvic tilt, sacral base angle and lumbar lordosis with a two-inch heel inclination (Franklin et al. 1995).

Some investigators have found a significant increase in the pelvifemoral angle and associated low back dysfunction (Maring-Klug 1982). While de Lateur, Giaconi, Questad, Ko, and Lehmann (1991) found no significant differences in either lumbar curvature, or in the angle of motion (hip flexion and lumbar excursion) with various heel heights (Earth Shoes™, barefoot, high heels (2.4 inch)) but they did find that the degree to which heels are compressible affects the skeletal impact upon heel strike cutting it up to one-half. It is suggested that the difficulties with high heels may be the hardness of the heel and the resultant shock, not the height itself. Short (1986), in a study of the effect of high heels on standing posture, also failed to find any differences in lumbar curvature across three heel-height conditions (barefoot, 1.75-inch heels, 3.5-inch heels). Furthermore, she failed to find any significant differences in pelvic inclination among any of the three heel heights. However, significant differences in the center of gravity among the subjects were found with the center of gravity being shifted significantly forward in those with both the low and high heels as compared to the barefoot condition (Douglass, Douglass, Rasgon, and Fleiss 1979).

On the other hand, Zohn (1988: 74–5) notes that

> . . . [t]he wearing of high heels . . . causes the wearer to stand with knees and hips flexed, lumbar lordosis accentuated, thoracic kyphosis exaggerated, cervical lordosis increased, and head thrust forward, which materially alters the center of gravity. The balance is thus disturbed and maintenance of normal tonus in supporting muscles is prevented. Such abnormal posture produces excessive wear and tear in every joint, from the occiput to the joints of the toes.

Controversy exists over the precise anatomical effects of high heels, but researchers agree that they contribute to a variety of musculo-skeletal problems.

These inconsistencies in research findings of the effects of high heels on posture may be explained by: (1) under laboratory conditions subjects wore high heels for only a short period of time which was not sufficient to produce the postural changes associated with long-term wear and fatigue; or (2) the stationary alignment of the lumbar-pelvis region may not be the same as during dynamic activities (Opila et al. 1988). While differing experimental settings may produce different effects on the musculo-skeletal system, and forces may be in opposite directions depending on whether the subject is stationary or walking, or whether the subject wore the heels for only a short time as compared to those who have suffered long-term, chronic exposure, the costs of wearing high heels is clear.

High heels cause a significant decrease in step length, in out-toeing (saggital rotation (typically 6–7°) of the foot during the weight-bearing phase of walking), and in the total range of movement of the talocalcaneal joint. Half of the subjects in an early study showed instability in the support phase of walking (Adrian and Karpovich 1966). It was also found that

wearing high heels increases muscle activity while standing. Increased activity in the soleus muscle while wearing high heels was found through electromyography, while the same subjects showed no change in electrical activity of thigh muscles (Joseph and Nightingale 1956). Gollnick, Tipton, and Karpovich (1964) also found that high heels extended the angle of the ankle when subjects were walking and standing. Running in high heels there was found to cause a reduction in the knee angle at all points resulting in the reduction amplitude of movement.

Shortened Achilles tendon

While not the only factor contributing to the dramatic shortening of the Achilles tendon, or tendo calcaneous, which joins the calcaneous to the gastrocnemius muscle, wearing high heels certainly plays a role. High-heeled shoes may allow the Achilles tendons in the back of the heels to shorten, leading to pain in the calves, the back, and sometimes even the neck. Very narrow heels tend to cause slight wobbling with each step because of the obvious difficulty of balancing large objects on a small, narrow surface. To accomplish this feat requires excessive muscular activity in walking. It may also make for short, prancing steps which, although perhaps fashionable, unduly stress leg and back muscles (Friedmann and Galton 1973).

Continuous wearing of high-heeled shoes eliminates ankle movement in walking, as well as the use of the foot as a lever. Wearing high heels lessens the effective length of the calf muscles and they contract to 'take up the slack.' Simultaneously, the opposing muscles on the anterior surface of the leg become weakened in their fight against the powerful gastrocnemius muscle and relax allowing further extension and abduction of the foot. The shortening of the calf muscles produces discomfort when walking barefoot or in low-heel shoes. Shortened calf muscles may cause the knees to be slightly flexed; this may in turn cause chronic flexion of the hips, all contributing to frequent lower back pain.

For those accustomed to wearing high heels, when the heel is lowered there is a sense of falling backward, accompanied by cramping of the calf muscles, weakness and pain in the inner medio-tarsal joint, swelling and sensitivity of the instep, and pain around the metatarsal bones. Lowering of heel height quickly is a sure way to develop all these symptoms. The only way that long-term wearers of high heels can adjust to low heels is to gradually reduce heel height over time, allowing the calf muscles to be supported by an arch support. Feet associated with shortened calf muscles are not normal feet; continuing to fit high-heel shoes only exacerbates the problem (Scholl 1931).

Head trauma

In rare cases high heels can cause severe closed head injury. Chang, Wong, and Richards (1994) report a case of a woman wearing cowboy-styled boots who slipped and suffered a full-force injury to the occipital portion of her skull resulting in large subdural and epidural hematomas, hemorrhagic contracoup contusions as well as secondary brainstem injury. Although not directly attributable to high heels, cowboy boots are characterized by a moderately high heel. The raised and tapered heel of cowboy boots '. . . [v]irtually eliminated the posterior movement arm, thus making recovery from backward imbalance difficult' (Severn 1964). In 1995 Continental Airlines lowered its requirement for its female flight attendants as a way of combating slips and falls which were one of the major occupational injuries plaguing the airline. Flight attendants now may wear shoes with heels as low as ¼ inch. The change resulted in an 80 per cent reduction in the number of falls (Sixel 1998).

It is true that individuals who wear high heels are no more likely to suffer head injury than someone roller skating, but the potential for injury is quite real. Would it not be interesting if the government suggested wearing the same protective gear while wearing high heels, as is the case for those roller-skating.

Increased energetic demands

High heels are energetically costly as demonstrated by a study designed to assess the energy costs of walking on a treadmill on a horizontal surface, as well as a 6 per cent grade, in three types of shoes: (1) loafer, (2) saddle, and (3) high heel (3 inch). High heels were found to be significantly more costly in energy than either barefoot, loafers, or saddles, which were not significantly different in energy costs. Compensatory changes in the center of gravity in the different types of footwear did not occur, but did take place at the knees or lumbar areas (Mathews and Wooten 1963). Ebbeling, Hamill, and Crussemeyer (1994) studied energy cost and lower extremity biomechanics in shoes with four different heel heights (0.5, 1.5, 2.0, 3.0 inches). Heart rate and O_2 consumption increased with heel height. Statistically significant differences in energetic costs were found between shoes with the 2-inch and 3-inch heel. No differences in energy expenditure were found among the three shorter heel heights. In sum, high heels (>3 inches) impose significant energetic demands on the wearer.

Reduced mobility

Not only are high heels more energetically expensive, they also make the wearer more conspicuous and less mobile. A convicted mugger is

reported to have said, 'We would wait under a stairwell in the subway station and then we heard the click of wobbly spiked heels we knew that we had one.' High heels make a woman vulnerable to physical attack (Konner 1988). She is not able to adequately run, kick, climb stairs, or jump. Wearing high heels not only makes a woman more vulnerable it also affects her gait. Instead of setting her heel down first, she sets the heel and toe down simultaneously, probably because the foot would be unstable with only a tall, narrow (stiletto) heel on the ground. Women take shorter strides and walk more slowly in high heels. For example, a woman in shoes with low, 1.4-inch, heels walked at 5.0 feet/second, taking 2.3 foot steps. The same woman in extreme (5-inch) stilettos reduced her speed to 2.3 feet/second and took steps only 1.3 feet long (Alexander 1992). Decreased velocity and increased stance time are a characteristic of high-heel gait (Opila-Correia 1990). On the other hand, de Lateur et al. (1991) failed to find significant changes in walking speed among individuals in various heel heights (Earth Shoes™ (negative heel), barefoot, 2.4-inch high heels).

Other

Ricci and Karpovich (1964) in a study of the effects of heel height on longitudinal arch, found that low heels (mean = 0.5 inches) decreased arch height 0.05 inches. Paradoxically, high heels (mean = 2.5 inches) actually increased arch height 0.06 inches. While this arch height increase, all things being equal, might be considered beneficial, the other attendant costs of high heels and the risks they pose offset any possible advantages to the increase in arch height. In addition to effecting arch height, high heels, and in particular platform shoes, can cause bilateral hemorrhages of the great toe nails (Douglass et al. 1979). Stewart (1972) found that when compared to barefoot controls, individuals in high heels (3.5-inch) experienced a 28 per cent reduction in the leverage of the foot causing and weight was transferred largely to the sesamoids predisposing individuals to heavy calluses.

Bursitis is a particularly common condition among individuals who wear high heels. In addition to calluses on the outside of the ball of the foot, high heels can cause a painful inflammation of the inferior metatarsal. All of this is the result of the excessive force that a high heel places on the ball of the foot (Scholl 1931). In addition, individuals wearing high heels can also suffer from Haglund's deformity and retrocalcaneal bursitis. Haglund's deformity has been given a variety of names (e.g., pump bump, cucumber heels, high-prow heels) but it is characterized by bony prominence on the surface of the calcaneus and often associated bursitis between the bony prominence and the Achilles tendon (Stephens 1994).

In this section I have outlined a number of biological costs of wearing high heels. In some ways, these are the costs that may have the most direct consequences for the wearer. However, in order to understand the complex interplay between cultural and biological factors that drive fashion, we must pay attention to the economic costs of wearing high heels. These economic costs are important for they demonstrate the degree of resources that wearers allocate to this practice. As an obvious rule of thumb, the more important the cultural or biological trait under consideration, the greater the resources the organism will devote to its acquisition.

Economic costs

Purchase

Direct economic costs of high heels are difficult to determine; however, Seale (1995) reports that, in a survey of slightly fewer than 1,000 subjects, individuals purchased on the average 5.6 pairs of shoes per year at an average cost of $50–200 each. Rossi (1993) estimates that in the US alone over $11 billion is spent on footwear per year, and of that 80 per cent is solely for sexual attraction. It is unclear how Rossi actually measures sexual attraction; the point is that people are willing to allocate significant resources to mate attraction.

Additional expenditures associated with advertising footwear should also be considered. Rossi (1993) estimates that manufacturers of footwear spend on the average of $350 million per year on advertising. While podocosmetics, another contributor to the overall cost of shoes in general, may contribute more than $500 million annually to the total costs (Coughlin and Thompson 1995).

In addition to the cost of footwear, there are the costs of treating problems attributable to high-fashion footwear. Coughlin and Thompson (1995) estimate that of the slightly greater than 600,000 surgical corrections in 1991 (bunionectomy, 209,000; hammmertoe repair, 210,000; neuroma excision, 66,500; and bunionette correction, 119,000), 75 per cent were the result of or aggravated by the use of high-fashion footwear. Estimated costs for the surgical procedures associated with these conditions is an additional $1.5 billion, coupled with the indirect costs (loss of time at work) could reach $3.0 billion (Coughlin and Thompson 1995). Coughlin and Thompson (1995) estimate a cost of $3,000 per procedure for surgical correction of foot maladies. They also estimate that individuals who have surgery lose four weeks from work as a direct result of the surgery. If these estimates are correct, the total economic costs of wearing high heels could exceed $16 billion.

Benefits of high heels

Enhanced appearance

Numerous authors have commented on the effects of wearing high heels, but most agree that the *only reason* to add heel height to a shoe is cosmetic (see Roth (1929) for a contrary opinion). If the only benefit is cosmetic, then appearance must be important to women wearing high heels. Appearance has been shown to be important in mating systems for both males and females (Fisher 1930). Possession of particular phenotypic characteristics has been shown to be key to mating success in a number of species of insects, birds, and mammals. The possession of certain phenotypic characteristics is one of the key elements in sexual selection. Not only do members of the courting sex sometimes use these phenotypic characters (e.g., big horns, elaborate beaks, decorative plumage) in direct competition with one another, the phenotypic characters are also used by the courted sex to indirectly indicate fitness.

Evolutionary history suggests humans are not exempt from the pressure of sexual selection. Humans are a mildly polygynous species (Daly and Wilson 1983; Murdock 1967) with both males and females who are in a monogamous relationship often seeking extra-pair matings. Data from a recent study suggest that while both males and females engage in extra-marital pursuits, males are at least twice as likely to do so as females at all ages (Table 1). Based on comparative animal ecology and behavior one would predict that males should be advertising through the display of their assets (physical or otherwise). And while males do advertise, in Western society, females also engage in equally conspicuous advertising and sexual signaling (Low 1994). Not only do we have male–male competition and female choice, but we also have female–female competition and male choice acting simultaneously.

There are a number of ways that high heels are reported to enhance appearance. Increased heel height creates an optical illusion of 'shortening' the foot, slenderizes the ankle, contributes to the appearance of long legs, adds a sensuous look to the stride, and increases height to generate the

Table 1 Age and sex of married individuals who had sex with more than one partner in the last twelve months (per cent)

Age	*Female*	*Male*
18–29	4.0	9.3
30–44	2.3	6.2
45–59	1.4	4.9

Adapted from Laumann, Gagnon, Michael, and Michaels (1994).

sensation of power and status (Coughlin 1995). Certainly these attributes are ones that many men would find attractive, and Rossi (1981: 698) concludes that

> . . . [h]igh heels may well be the most potent aphrodisiac ever concocted. When worn by women, the high heel sensuously alters the whole anatomy – foot, leg, thigh, hips, pelvis, buttocks, breasts, etc. . . . Men are perfectly frank in admitting that high heels stimulate their sexual appetite. They seldom fail to express their predilection for them, and women, consequently, assign to stilted shoes all the magic of a love potion.

Postural changes

Rossi (1993) notes that high heels go much beyond sexual symbolism and actually enhance the sexual attractiveness of a woman through various means:

1 by giving more shapely contours to the ankle and leg;
2 by making the foot look smaller, the arch and the instep more femininely curved;
3 by causing postural changes that accentuate voluptuousness in the shape and movement of the lower limbs, the pelvis and buttocks, the abdomen and bosom, as well as the curve of the back;
4 by feminizing the gait due to the shortening of stride and the appearance of a mincing step, that some consider provocative (Cornfield 1978);
5 by adding to the height of the wearer (Buss 1994) they provide a psychological and emotional uplift that enhances sexual attraction.

Obviously, high heels can have a dramatic effect on the posture of the individual. Flügel (1950) notes that high heels reduce the protruding abdomen, and give a prominence to the bosom. The high heel reshapes the body silhouette, the angle of the pelvis is increased thereby increasing the rearward protrusion of the buttocks. Rossi (1993) notes that two-inch heels change the angle of tilt of the pelvis from 25° while standing in stocking feet, to 45° in a two-inch heel, or 55° in a three-inch heel (see Figure 4). Moreover the mobility of buttocks while in high heels is at least twice that when walking barefoot or in flat heels. The body takes on the look of a pouter pigeon, with lots of breast and tail balanced precariously on a pair of stilts (Rossi 1993). These anatomical changes brought about as a consequence of wearing high heels have been recognized by authors and song writers for decades.

Mae West once said that, 'it is better to be looked over than overlooked.' The benefits of high heels in sexual signaling are clear. Women wearing high heels draw attention to specific phenotypic characters that they consider important in attracting a superior mate, appearing taller and thinner; having large, firm breasts; having an attractive waist/hip ratio (Buss 1994). Fisher (1992) observed that high heels unnaturally arch the back, tilt the buttocks, and thrust the chest out in a come-hither pose. The noise of the spike heels also draws attention as well. Human females stretch their necks, file their teeth, pierce various body parts, scar their breasts, parch or tan their skin, and walk in potentially debilitating and life-threatening high heels to advertise their sexuality with the goal of attracting the highest-quality mate.

Conclusions

Wearing high heels can be explained in both cultural and biological or evolutionary terms. One of the paradoxical aspects of human behavior is the regularity with which we engage in behaviors which are likely to reduce our Darwinian fitness. We routinely engage in a variety of behaviors that we know are deleterious to long-term survivorship that includes such disparate practices as overeating, smoking, drinking too much alcohol, as well as some less obvious gustatory choices.

Humans, in modern Western society, routinely consume 6–18 grams of salt every day, at least an order of magnitude more than the presumed daily nutritional requirement (Beauchamp 1987). As evidenced by the extraordinarily high levels of obesity in Western society, it is clear that we also consume excessive quantities of sugar (Drewnowski 1989; Drewnowski and Greenwood 1983). In addition to salt and sugar, Americans consume large quantities of fats. To add insult to injury not only do we have a 'sweet tooth' and a 'salt tooth' but we have a 'fat tooth' as well. Today, the diet of the average American is composed of about 40 per cent fat calories. These preferences are acquired early in life, since mammalian milk is essentially a concoction of fat and sugar, this makes good evolutionary sense. In our evolutionary past these preferences likely came under strong selective pressure and the consumption of foods containing salt, fat, and sugar were likely fitness enhancing. However, in our modern environment of superadequate nutrition and little exercise, these evolved preferences have deleterious consequences (e.g., hypertension, cardiac arrest, myocardial infarction, diabetes, cancer).

I have argued in this paper that wearing high heels is a culturally derived and defined trait, but this cultural trait is likely influenced by phylogenetically-ancient evolved predispositions to engage in fitness-maximizing behaviors. In this regard, there is obviously no predisposition to wear high heels specifically, but there are more general tendencies to engage in behaviors that will attract high-quality mates. Human females employ a variety of devices to signal intentions about mating, and like other cultural accoutrements, high heels serve a mate-attraction function in human society that more than offsets the potential costs associated with their use. Like the tail of peacocks, high heels communicate important information about mating as well as biological fitness. The intriguing aspect of all of this is the extent to which humans will engage in activities that are potentially fitness reducing in the strict Darwinian sense, but strongly implicated in mate attraction through sexual selection.

In closing it is important to note we have the capacity to direct our own behavior in ways that other animals cannot. As Richard Dawkins (1988) noted a number of years ago, we have the ability to overcome 'the tyranny of our genes.' While fashion may have dictated footwear that was very costly, but potentially fitness enhancing via sexual selection, recent surveys suggest that women in America are changing the shoes they wear, particularly in the workplace. In a survey of 500 women who work outside the home, only 25 per cent of those surveyed reported regularly wearing shoes with a heel greater than one inch to work. Less than 3 per cent of those surveyed acknowledged wearing shoes with a heel height greater than 2.25 inches. The changes in shoe preferences were most evident among women 20–30 years old with only 16 per cent wearing heels higher than one inch, while among women 40–50, 28 per cent reported wearing high heels. These results show a significant change from the results of a similar survey conducted in 1990 indicating that 37 per cent of the women wore high heels in the workplace (American Orthopaedic Foot and Ankle Society 1998). Of course, the interesting question one should ask is if these women surveyed wear high heels on other occasions and specifically what those occasions were.

It is unlikely that we will ever be able to prove that wearing high heels is a component of sexually selected mating strategies in modern humans. The fact that women endure the costs of wearing high heels may also be explained as a consequence of the cultural domination and subjugation of women. This argument suggests that if left to their own devices, women would not choose to wear high heels. In fact, it would make good Darwinian sense for women to avoid wearing high heels at all, and hence avoid all the potential costs.

There are no long-term studies of the fitness of women that wear high heels as compared to those that do not, so a definitive answer to these questions is unlikely in the near future. Empirical tests of the fitness of high-heel wearers would be methodologically difficult. Controlling for all of the correlated variables (SES, age, body size, early rearing conditions, etc.) would prove a real challenge to the researcher. Perhaps the only conclusion

one can reach is that the sexual selection hypothesis is at least as good as other hypotheses advanced to explain why women wear high heels.

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Notes

1 *Striding*, as opposed to hopping, bipedal locomotion has evolved in two vertebrate lineages, archosaurs and primates, and is represented today by humans and birds (Gatesy and Biewener 1991), while *saltatory* bipedalism is found among macropod marsupials, some rodents and some birds (Djawdan and Garland 1988). Interestingly, and not so surprisingly, anthropologists concerned with the evolution of human locomotion have largely overlooked birds or other vertebrates as taxonomic groups that might provide important information on gait and limb usage potentially furthering our understanding of human bipedalism. In fact, birds constitute a group of species that exhibits many more forms that are adapted to a striding bipedal locomotion as compared to primates. Gatesy and Biewener (1991), in a careful analysis of the gaits of seven species of ground-dwelling birds (0.045–90.0 kg), found that humans and large birds exhibit striking similarities in stride length and stride frequency in relation to speed with a given gait, but the transition between gaits occurs abruptly in humans: step length, limb excursion angle and duty factor all fall sharply in the walk–run transition, while birds have a much smoother gait transition in all of the above-mentioned parameters. In fact, the transition from walking to running, while obvious in humans, is not at all conspicuous in the large birds. In summary, humans have a stiff run that favors storage and recovery of energy, whereas birds have a type of run that favors stability. Gatesy and Biewener (1991) suggest that the differences between human bipedalism and that of bipedal dinosaurs, possessing a large counterbalancing tail, are similar to those between humans and the extant ground-dwelling birds.

2 Recent discoveries of *Australopithecus anamensis* and *Ardipithecus ramidus*, coupled with the re-evaluation of the Sterkfontein postcranial material (e.g. Little Foot) suggest a complicated pathway for the evolution of bipedalism in the hominid line. It has been suggested that bipedalism could have two separate origins in early hominids, one in South Africa and the other in East Africa (Shreeve 1996).

3 See Scholl (1931: 189) for an illustration of the effects of high heels on body posture and center of gravity.

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