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Epistemology: The Relationship between Power, Science, and Ideology

A HISTORY OF MEDICAL SCIENTISTS ON HIGH HEELS

Marc Linder and Charles L. Saltzman

For 250 years medical scientists have propagandized about the health hazards of high-heeled shoes, which originated four centuries ago. Physicians, however, largely unaware of their own profession's tradition, keep reinventing the diagnostic wheel. This professional amnesia has held back the momentum of the process of educating the public. Consequently, despite these warnings, millions of women continue to wear high-heeled shoes. This article describes the history of the medical profession's recognition of this worldwide health problem and the current understanding of the deleterious and often irreversible biomechanical effects of high-heeled shoewear. The article emphasizes that the reemergence of high heels and of medical interest in them in the third quarter of the 19th century, following their disappearance in the wake of the French Revolution, was associated with increasing pressure by employers to wear such shoes for long hours at work. Although medical scientists have recognized this specifically occupational phenomenon for more than a century, full-scale epidemiological studies may be necessary to bring about substantial social-behavioral change.

I have heard a story that a lady who had been wearing these high-heeled shoes went to one of the most celebrated orthopedic surgeons in New York City for some spinal trouble, and when, after examining the case, he found that she was wearing a pair of these fashionable shoes, he immediately seized them and with language more forcible than elegant pulled off the heels and flung them away, following them with a shower of denunciations, and prophesying all sorts of ill results should the abominable fashion be continued.

Barker, 1882 (1, p. 262)

Ladies who must *wear certain fashionable boots should, as a preliminary measure, have the three middle toes amputated. The operation would add to their comfort, would render their gait not one whit more awkward than it is at present,*

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and would be but a very little less sensible than the Chinese practice of deforming the feet in infancy.

Treves, 1884 (2, p. 26)

We often fail in our efforts at successful treatment of pelvic conditions . . . in patients that wear very high heel shoes solely as result of the high heel shoe. . . . The pain is very severe at times, and the paroxysms frequent, but I have found it . . . impossible in most cases, to induce those who have this habit to correct it by adopting the use of a common sense shoe. As a matter of fact, the doctor is unable to regulate the wearing apparel of the members of his own family, and is advised not to waste his time in attempting to make reforms regarding ladies' dress.

Smythe, 1912 (3, p. 152)

If the whole European philosophical tradition consists of a series of footnotes to Plato (4, p. 63), then today's advanced-technology measurement techniques for quantifying the relationship between wearing high-heeled shoes and various musculoskeletal ailments can be viewed as a series of quantitative footnotes to the observations offered by the 18th century orthopaedists and anatomists, Winslow, Andry, and Camper. Unlike modern philosophers, however, who are intensely conscious of the ancient Greek origins of their discipline's questions and approaches, contemporary orthopaedists are largely unaware that they are deeply embedded in a hortatory monologue that physicians have been carrying on with wearers of high heels for 250 years. This type of professional amnesia, which is common in medical specialties, is especially detrimental when paired with laypersons' ignorance of the long history of high heels. If, instead of mistakenly believing that such shoes are 20th century creations, people understood that they have been worn for 400 years and that physicians during most of that time have been advising against their use, then perhaps the educational process would gain greater momentum. If each successive generation of physicians did not have to keep reinventing the diagnostic wheel, and the sediments of centuries of continuous medical concern with high heels seeped into popular consciousness, as has recently been happening with tobacco use, then the chances would be enhanced of helping hundreds of thousands of women avoid the totally unnecessary pain, disfigurement, and immobility about which Winslow, Andry, and Camper began warning the world so long ago.

What at first glance may appear to be a disjuncture between two competing contentions—namely, that on the one hand medical researchers have documented the harmful effects of high heels for centuries (without bringing about changes in shoe-wearing practices because their work is not widely known), and that on the other hand workplace-centered epidemiological studies are still necessary to effect change—is in fact a reflection of the need for medical researchers to develop evidence that will be more persuasive to the general public. The public health problem today is not that the causes of such injuries are not well known—

the basic biomechanical causation has been fairly well understood for a long time—but that the lack of epidemiological studies has left conclusions about the long-term effects scientifically unproven. This lack of accumulated epidemiological evidence has been a major barrier to dissemination of the kind of dramatically persuasive information that has induced millions of people not to smoke tobacco.

Although this article presents considerable little-known information about the historical course of the use of high-heeled shoes in the United States and Europe, its focus is medical science's analysis of the health consequences of wearing such shoes, not the social construction of clothing. One significant obstacle to writing such a social history is the absence of reliable data on the proportion of people who have worn high heels in any given year or over time. It is, for example, unclear whether relevant fluctuations in the proportion of women wearing high heels have taken place during the 19th and 20th centuries. Perhaps the only generally valid point we can make here is that if it was only after the latter part of the 19th century that the wearing of high heels spread from the upper classes (to which most contemporaneous fashion reports referred) to working-class women, the overall proportion of women wearing high heels must have risen.

The reasons for the advent of fashionable high-heeled shoes in Europe about the year 1600—as contradistinguished from their use several centuries earlier by oriental cavalry (5)—may still await clarification (6), but historians are clear that their introduction constituted "one of the most revolutionary achievements [which] ushered in a whole new epoch of the presentation of corporeality, in which we today are still living and with the effects of which we are still working" (7, p. 166). Although originally and through the 18th century both men and women of the upper classes adopted this new style of shoe, its capacity for altering human posture was exerted most strikingly on women, forcing the abdomen in and the breast out, drawing in the back, making the pelvis more prominent, straightening the knees, and making the thighs firmer. During the reign of Louis XIV, the elegant aristocratic leg became fashionable and for the first time women's shoes developed along their own path. Of the impact on the king himself the British novelist Thackeray later said (8, p. 404):

> But a king is not every inch a king, for all the poet may say. . . . Majesty is made out of the wig, the high-heeled shoes, and cloak, all fleurs-de-lis bespangled. As for the little lean, shrivelled, paunchy old man, of five feet two, . . . Put the wig and shoes on him, and he is six feet high.

High-heeled buckled shoes remained obligatory courtly attire for men through the 18th century, but they did not attain the heights of aristocratic women's shoes. Women's high heels became fashionable in Germany during the last decades of the 17th century (9; 10, p. 160). In Britain, however, men's heels did reach 5 inches toward the end of the 18th century; by 1740, they had once again fallen

to 1 inch or less, although they briefly shot up to 6 inches in the 1770s (11, pp. 65, 74–77). No wonder that women who wore 6 inch high heels "seldom or never went out": balancing a towering hair-do while encased in a tight corset made movement in such footwear a difficult task (12, pp. 169–170).

It was not long before physicians began issuing warnings about the deleterious effects of wearing such shoes. In the wake of the Enlightenment's attack on unreason and unnatural conditions, the Danish anatomist and physician Jacob Benignus Winslow (1669–1760), whose textbook on anatomy was authoritative for almost a century (13, p. 338), delivered a talk in 1740 before the French Académie Royale des Sciences in which he sharply criticized women's high-heeled shoes for their adverse impact on the wearers' health. Winslow's "Anatomical Reflections on the Discomforts, Infirmities, etc. which Happen to the Human Body as a Result of Certain . . . Clothing" (14; English translation of title) is worth quoting at some length both because it may be the first such published medical critique and because its analysis is largely couched in biomechanical terms still acceptable to orthopaedic surgeons. Winslow traced the loss of the free movement of the foot bones in their natural state to shoddy shoeing (14, pp. 63, 65):

> women's high footwear totally changes the natural conformation of these bones, renders the feet extraordinarily bent and bowed, and even incapable of being flattened, as a result of the unnatural union or forced anchylosis of these bones . . . ; for these high shoes bring it about that the posterior extremity of the calcaneum bone, to which the large Achilles tendon is attached, is continually much more elevated, and the front of the foot much more depressed, than in the natural state. Consequently, the muscles that cover the back part of the leg, and that serve by attachment of their tendon to stretch the foot, are continually in an unnatural contraction, whereas the anterior muscles, which serve to bend the foot in front, are on the contrary in forced elongation. . . . Not only the muscles of the large Achilles tendon which serve the extension of the foot, but also the anterior muscles which serve the extension of the toes, are as a result of the height of these shoes continually in a state of forced contraction; and not only the anterior muscles which serve the flexion of the foot, but the posterior muscles which serve the flexion of the toes, are at the same time as a result of this height continually in a state of forced elongation. This continual state of contraction of some and of tugging of the others of these muscles can only cause sooner or later some more or less considerable harm to their vessels, both blood and lymphatic, and to their nerves, and moreover by means of the communication of these vessels and of these nerves with the vessels and the nerves of other more distant parts, even with those of the viscera of the abdomen, etc., occasion discomforts that one would attribute to a totally different cause, and consequently one would continually bring to bear remedies not only useless but accidentally harmful and dangerous. . . . It is true that this forced state of shortening of one part and of elongation of the other part with time becomes

> the natural state so that those who are habitually accustomed to it can almost not walk without pain and without suffering in low shoes; but that does not prevent this unnatural posture from being the cause of certain infirmities which appear not to have any relation to it.

The very next year, Nicholas Andry (1658–1742), the most prominent orthopaedist in France in the first half of the 18th century (15, p. 545), observed in his treatise *Orthopédie* that too high heels induced curvature of the spine in young people and that, for this reason especially, girls should not be given high heels before the age of 15 (16, p. 72). In 1781 Peter Camper (1722–1789), an outstanding 18th century European comparative anatomist, wrote an entire *Dissertation on the Best Form of the Shoe* (17; English translation of title), an important contribution to the physiology of locomotion, in which he devoted special attention to the class distribution of shoe wear. Whereas "bourgeois women" adopted "this absurd fashion" of high and slender heels from the old and young women of "good form," "our peasant women are wiser . . . providing themselves with shoes that make their body steady and render walking easy" (17, p. 7). Camper went so far as to warn: "The wealthy women walk . . . , by reason of the height of their heels, on the fore-ends of their feet, and consequently, very badly; they walk, if it is permitted to make this comparison, like the majority of quadrupeds—on their toes only" (17, p. 46). In addition to the deformation of the toes, Camper focused on the greater risk of sprains caused by the fact that high heels displaced the whole body's center of gravity. In particular he speculated that high heels explained the much greater incidence of kneecap fractures suffered by women in Amsterdam—an injury that occurred very rarely in men (17, pp. 30–31). (A century later a British surgeon still had to warn that the small size of high heels tended to trip wearers, leading to serious accidents (18, p. 106).)

Camper also inaugurated a medical discourse on the uterine-related consequences of wearing high heels, a discourse that persisted into the beginning of the 20th century (17, pp. 32–33):

> Overly high heels have yet a terrible disadvantage for women when they are pregnant. To maintain the erect position, females . . . are compelled to carry the head and shoulders backwards, when the spinal column becomes relatively more curved at the kidneys, and the pelvis . . . narrow, inasmuch as the lumbar vertebræ, where they are connected to the os sacrum, which forms the posterior part of the pelvis, are pushed forward into this cavity; the head of the child, which must pass through, is then hindered, and very often so wedged that one must pull it out with instruments, which, however well devised, act with a force sometimes detrimental to the child or to the mother, and often to both.
>
> I am much persuaded that the fashion of wearing high heels, solely intended to give grace to the body of the fair sex, is the cause of many

> difficult labours, especially among the nobility. Peasant women do not suffer from it, the good form of their heels saves them from it.

By the early 1780s, a British exemplar of the flourishing genre of home guides to health was sufficiently steeped in the new orthopaedic learning initiated by Winslow that it warned the lay public: "Not a female in twenty can be said to walk well, which is certainly owing to shoes with high heels and narrow toes" (19, p. 85).

The medical Enlightenment's campaign against high heels bore fruit in the wake of the French Revolution, whose popular-class advocates brought about a "déclassement" that led to the disappearance of high heels, which they associated with the aristocracy (20, pp. 95–100; 21, pp. 85–86, 132). Moreover, at least for men, the sans-culottes' abolition of the aristocrats' knee breeches undermined the high heel's function of accentuating "a well-turned leg" (22, p. 139). But the new clothing orientation, paired with Rousseau's back-to-nature philosophy (23, p. 466), also quickly led to women's high heels' becoming and remaining passé for several decades (5, 9). In England, too, the "flat 'pump' . . . supplanted the heeled shoe, and remained in fashion for some 40 years" (11, p. 80). Looking back from the 1840s, a boot maker to Queen Victoria could boast that the non-high-heeled Wellington boot "seems to have settled the laws of fashion respecting the feet, as decisively as the battle of Waterloo settled the affairs of Europe" (22, p. 143). The elimination of the high heel on women's shoes effected by the Revolution in France (22, p. 139) extended to the United States as well, so that in "1790 heels disappeared" (24, p. 386). According to Hall (22, pp. 143–144):

> The levelling spirit of the French revolution, seems to have reached even to ladies' shoes; for we find that about 1790, the high heel was dispensed with, and shoes without heels were introduced. We have heard ladies of the olden time, say that it was hard to come down in this manner all at once; . . . our grandmothers were compelled for a long time to do penance to the tyrant fashion on tiptoe.

As late as the 1850s, a chronicler of Philadelphia, who bizarrely asserted that in the 18th century high heels had "exempted" women from "crumpled toes or corns" and enabled them to "pinch their feet with impunity" by "so press[ing] upon the balls of their feet, as necessarily to give the flattest and easiest expansion to their toes," lamented that by his time they were "deemed so unfitting for pretty feet" (25, p. 192). Yet by the third quarter of the 19th century, high heels had once again become fashionable in Europe and the United States (not for the first time as some amnesiac authors believe (26, pp. 196–197))—but this time only for women's shoes (27, p. 66). Historians of material culture speculate that industrialization crucially determined new sets of dichotomized gender roles, which

also found expression in clothing. Whereas before the French Revolution the great dividing line ran between aristocracy and the people, industrialization created a sharp "opposition between the active, financially independent and thus more powerful husband and the domestically dependent wife. Men's and women's fashions thus began for the first time in history to develop completely away from each other." In contrast to the enterprising bourgeois men who needed practical clothing, their wives, remitted to the private and family sphere, "remained true to the ideal of visible idleness" for which the "erotic-unpractical high-heel shoe" attained representative status (9, pp. 55–56; cf. 28, pp. 104–106).

In the wake of the return of high heels around the middle of the 19th century, physicians resumed their attacks. In 1858, Hermann von Meyer, the German-born director of the anatomical institute in Zurich, published a book entitled *Die richtige Gestalt der Schuhe (The Correct Form of Shoes)* (29), which emphasized that high heels shifted the weight of the body onto the toes with the same injurious consequences that too short shoes would cause. In Britain, too, voices began to be raised in tandem with heels. In 1861, James Dowie, a medically trained shoemaker who published his own work together with an English translation of Camper's book, likened the effect of walking in high heels to the "very fatiguing attitudes for the muscles" associated with walking downhill: "There is perhaps no attitude under which the tendons and muscles of the foot and ankle are more liable to be sprained or otherwise injured" (30, p. 139). The same year, in his small treatise on *The Human Foot and the Human Hand*, Dr. G. M. Humphry, a lecturer on anatomy and physiology at the University of Cambridge, stressed that the high heel, by driving forward and cramping the toes, "tends to aggravate the evils which are caused by the insufficient and ill-adjusted space which is allowed for the toes" (31, p. 106). This flurry of scientific activity prompted *All The Year Round*, a magazine edited by Charles Dickens, to observe in 1861 that it was "only within the last four years that we may consider this matter of the right shape of a boot to have been fairly and practically settled for us by the anatomists," thus making possible "the ruin of a fashion that has put thousands of people into actual torment of pain" (32, p. 512).

As early as 1868 a British women's magazine noted: "High-heeled boots and shoes are universal, notwithstanding that medical men have been writing very severely against them. They say that the fashion causes corns, cramps, lameness at an early age, lessens the size of the calf, and thus makes the leg lose its symmetry" (33). (These remarks underscore the socially constructed character of the perception of the effects of high heels: "Twentieth-century woman is told a high heel makes the leg look slimmer, now a desirable quality" (34, p. 48).) On the other side of the Atlantic, *Harper's Bazaar* in 1868 editorialized against "inordinately high and narrow heels [which] deform the foot" (35). Soon, even local newspapers in the United States were carrying articles lamenting "the high pointed heels and narrow soles with which the ladies in the past have tortured themselves" (36).

In 1873, the campaign for women's dress reform received an important impulse from a series of lectures organized by Abba Louisa Goold Woolson, an essayist and teacher, in her capacity as an officer of the New England Women's Club. Speaking in Boston and elsewhere, four female physicians and Woolson criticized a wide range of clothing, but especially corsets, as threats to various vital organs and bodily processes. Dr. Mercy B. Jackson (37) paid special attention to women's shoes. Men's footwear she praised as having "toes . . . wide enough to allow them to rest upon the sole separately, producing the elastic rebound which enables one to walk without fatigue." Although recognizing that some men were "foolish enough to cramp their feet in narrow boots," she insisted that they were "a very small minority, and . . . not the leading ones . . . copied by the masses." In contrast, the narrow tip of women's boots "prevents the action of the muscles of the foot in walking, and throws the whole labor upon the muscles of the leg, thus disabling our women from healthful exercises to such a degree that not one in twenty can walk three miles without complete exhaustion" (37, pp. 68, 73). Jackson regarded high heels as "lay[ing] the foundation for consequences more fatal than" Chinese foot binding, and as (37, p. 75):

> one of the most fruitful sources of disease. They not only cause contractions of the muscles of the leg, so great in some instances as to make a surgical separation of them necessary, but by raising the heel they bring the weight of the body upon the toes, and thus induce corns and bunions that alone suffice to make locomotion very painful. Moreover, by inclining the body forward, they throw the uterus out of its normal position, and oblige the ligaments that are designed to steady it to remain constantly in action, in order to restore it to its proper place. These muscles kept continually on the stretch soon lose their contractile power; and then the uterus, thrown out of place by the unnatural pose of the body, remains in this abnormal position, and often becomes adherent to the adjacent parts. When this is the case, a most serious disease is entailed upon the sufferer.

This last component of the diagnosis is notable because, unlike the basic biomechanical explanation, today's medical learning finds it empirically unsupported. The likelihood of such erroneous diagnoses was enhanced by the research techniques of the period, which, at least for this type of symptom, did not provide for large-scale clinical surveys. Practicing physicians who used professional journals to communicate to their colleagues results based on examinations of a handful of patients were bound to report scientifically hit-or-miss conclusions. Noteworthy here is that Jackson and later physicians erred on the side of overemphasizing the adverse effects of high heels. Physicians in the late 19th and early 20th century were, moreover, inclined to relate alleged uterine derangements to all manner of industrial conditions, including prolonged standing, heat, and confinement, as well as to the wearing of corsets and "suspension of heavy skirts from the loins" (38, pp. 63, 91; 39, pp. 27, 39; 40, p. 45; 41, pp. 146–174).

In 1874, Sir James Paget (42) delivered a clinical lecture at St. Bartholomew's Hospital in London on "Maladies Produced by Boots and Shoes," in which he described high heels as one of the possible causes of mutual compression of the toes. He observed that women's high-heeled boots "will always be causing them to walk down-hill, however level the path may be, thus driving the foot more and more to the front." By the late 1870s and early 1880s, Britain, too, witnessed the rise of a dress reform movement culminating in the formation in 1881 of the Rational Dress Society, which protested the wearing of high-heeled and narrow-toed footwear (43, pp. 116–117; 44, p. 282; 45; 46, pp. 51, 53).

In 1876, a Dr. Onimus (47) read a paper—the published version of which soon influenced medical opinion on the other side of the Atlantic—to the Medical Society of Paris on recent cases of patients' foot problems caused by high- and thin-heeled shoes. The wearing of these so-called Louis XV ankle boots by women and girls was then a recent and rapidly expanding custom after the style, which had caught on early in the 18th century, had begun to disappear by the end of that century. The advantage, "from the point of view of coquetry," of producing the appearance of a smaller foot was paired with sharp pains in the leg muscles. Interestingly, Onimus developed a biomechanical explanation of the pain, in opposition to the view that attributed the problems to young girls' "pathological nervous state . . . which one considered a more or less peculiar manifestation of a hysterical state." In order to relieve the lancinating pains caused by the cramps associated with the constant muscular tension needed to maintain their equilibrium while wearing high heels, young girls were forced to rest in bed for several days. Like Jackson, Onimus diagnosed an anteflexion of the uterus as brought on by the pelvic tilt associated with high heels. Going further, however, he in turn held them accountable for the fact that all of these patients were also "tormented by the frequent need to urinate."

By 1881 a British physician reported an occupationally related backache caused by "the wearing of high-heeled boots, which necessitates the continuous action of the muscles of the lower part of the spine, in order to maintain the proper balance and erect position" (48). When one patient, a 17-year-old assistant in a large London dry goods store, "a delicate-looking blonde, of pale lymphatic temperament," complained of backache and aching in the calves of her legs, the physician could find nothing wrong with her. But as he was about to leave the examining room, he "noticed that she was wearing very high-heeled boots." He instructed her to "wear woollen stockings, a pair of soft-soled house-slippers . . . and, when she went out, [to] put a pair of galoshes over them." After she ceased wearing the high heels, she never suffered from backache again. Thereafter, whenever "young ladies from shops in the City" consulted the physician, he invariably asked them whether they wore high-heeled boots.

The new wave of warnings from the medical profession incorporating an occupational component and the specific focus on "shop-girls" were hardly coincidental: as large numbers of women began working as sellers, especially in

clothing stores and department stores (49, pp. 193–194)—women in sales occupations in the United States increased 24-fold from 1870 to 1900 (50, Table IIA, p. 212)—they were subjected to formal pressure by employers and informal cultural pressure to wear precisely the kinds of fashionable shoes that their customers wore (51, pp. 55–56; 52, p. 300; 53, pp. 180, 183; 54, p. 126; 55, p. 129). The phenomenon of large numbers of saleswomen in dry goods, clothing, and department stores wearing high heels for 12 to 14 hours a day, six days a week, prompted physicians in Paris, London, and New York not only to report on their patients' foot ailments, but also to launch campaigns to reform women's dress and to enact statutes requiring employers to provide seats for their female employees so that they would not be compelled to stand in those shoes all day (56, p. 47; 57, p. 421). In 1875, Dr. Azel Ames, Jr., a physician and special commissioner for investigation of the Massachusetts Bureau of Statistics of Labor, recommended seats for saleswomen whose employers cruelly forced them to stand all day (51, pp. 54–59, 137, 145). Under the heading, "Slavery in the West-End," Dr. Arthur Edis (58) wrote a letter to the London *Times* in 1878 warning of the health consequences of constant standing, and two years later *The Lancet*, Britain's leading medical journal, launched an editorial campaign against this "cruelty to women" (59).

By the early 1880s the medical profession on the western side of the Atlantic also began to report on the consequences of wearing high heels. The year 1882 witnessed publication in a Cuban medical journal of an article inspired by Dr. Onimus, pointing out the infirmities that the "fair sex"incurred in wearing high heels (60). That same year Samuel Busey read a paper at the annual meeting of the recently founded American Gynecological Society entitled, "The Influence of the Constant Use of High-Heeled French Shoes upon the Health and Form of the Female, and upon the Relation of the Pelvic Organs" (61), in which he speculated that the deflections of the skeleton associated with wearing high heels might be the cause of postural disturbances and spinal curvatures such as lordosis. Following in Onimus's footsteps, Busey added constipation, menstrual disturbances, vaginal discharges, and sterility to the catalog of possible maladies brought on by pelvic tilt (61, 62).

That the young profession's sense of empirical skepticism was alive emerged from discussion contributions by two past presidents of the American Gynecological Society. Fordyce Barker, the best known obstetrician of his time in the United States (63), while unable to identify any fallacy in Busey's paper, observed that he had often (1, pp. 261–263):

> been forcibly struck by the fact, that, practically, the results are quite different from what science teaches us they should be. With regard to this very matter, it is now some twelve or fifteen years since what are known as the Louis Quinze high-heeled shoes came into fashion in this country, and having had more or less of the high-heeled clientèle I have been watching their effects for

> some time. We have many American women who go abroad and bring back French fashions and French shoes, and they have been worn amongst us abundantly for at least eight or ten years. . . . For many years I have been accustomed to watch this class of patients to see what symptoms would occur among those who did wear high-heeled shoes that did not develop in those that did not wear such foot gear. I should like to know whether any one has noticed that the people in that class of society who wear high-heeled shoes have affections of the pelvic organs or other difficulties traceable to this cause. . . . According to science there should have been produced some special ills, and I think Dr. Busey has most ably proved that the elevation of the heels, with the changes which they produce, ought to be followed by all these changes in the angles and curvature of the body which he so logically and clearly describes.

T. Gaillard Thomas also detected a gap between theoretical prediction and clinical observation: "I have felt that it should be bad, and that women who wear high-heeled shoes should surely have uterine displacement, but I have been . . . disappointed with regard to it, although I have had under observation women who have indulged in this pernicious habit for years" (64). In response to these implicit pleas for what today would be called randomized trials, Busey conceded the speculative nature of the etiology: "No one doubts the injury of such a change upon the feet and effect upon the normal curves of the spine. The other inferences which I have made are simply deductions, not positive conclusions" (65). Evaluations of these early gynecologically oriented analyses of high-heel wearing should take into account the judgment by the president of the American Gynecological Society three decades later that of the more than 1,000 presentations before the organization between 1876 and 1914, only 27 had been "excellent" and 42 "creditable" (66, p. 120).

So much medical knowledge had permeated popular consciousness by the 1880s that even Oscar Wilde knew that high heels' "inevitable effect is to throw the body forward, to shorten the steps, and consequently to produce that want of grace which always follows want of freedom" (67, p. 945). Perhaps the medical warnings did have some practical effect: by the turn of the century, Mary Melendy (68), a physician, could remark: "In purchasing shoes at one time it was next to impossible to find them with low heels." Indeed, the attendant misery of corns and bunions led to a reaction against high heels and a turn toward "commonsense shoes" (68, p. 198).

The beginning of the 20th century witnessed a turn in fashion away from restrictive clothing and toward flowing dresses and higher hemlines: "For the first time in history, legs and feet had become a center of fashion attention" (69, p. 21). Even as shoes assumed this new role, physicians complained that the "vast importance of the question of proper shoes is not rightly appreciated by our profession" (70, p. 213). Such professional concern seeped into popular consciousness. For example, the *Ladies Home Journal* in 1908 published a piece

replete with X-ray photographs of the foot in high- and low-heeled shoes demonstrating how "the bones of the foot are forced into an unnatural relation to each other" (71). More serious than this abnormality, according to the physician-author, was the fact that high heels caused the wearer's body to be thrown forward in order to maintain equilibrium, and that, because she could not keep the shoulders thrown back, the chest sank in: "Full or normal breathing is impossible, and there are, as a result, areas in the apex of each lung unused . . . because the muscles which expand them are not in a position to exert their full power. [W]ith lessened lung-capacity . . . every organ of the body suffers." Over time the cumulative effects "transform the girl of spirit into a listless person . . . the healthy, hearty, robust person to a semi-invalid or a total one" (71). Again, this latter diagnosis finds no favor among today's physicians.

By the time of World War I and in the wake of the more intensive contact with France, the purported source of high heels as a fashion—and where the medical profession had carefully diagnosed the conditions suffered by women wearing 10-centimeter heels (72)—U.S. doctors were warning that high heels also had more remote effects such as perpetuating if not producing "those postural strains which are so often referred to the knees, to the sacroiliac joints and to the back" (73, p. 209; 74). A reader of *The New York Times* knew enough to complain that although "high-heeled shoes" were "unhygienic, throwing the spinal column out of line" (75):

> The vogue of French heels is even on the increase. The shopgirl who stands all day wears them, the nursemaid who trundles the baby wears them, and even my laundress wears them as she stands at the tubs. Why condemn the 'lily-footed Chinese' for binding her toes if we also deform our feet.

By the last year of World War I, *Scientific American* reported on the research performed by French doctors on the derangement of the pedal equilibrium: "The muscular action, the orientation, and the mutual relationships among the elaborately articulated members of the human foot are thrown out of gear; in particular the arrangement of those joints of the foot which support the weight of the body is profoundly changed" (76). High heels created fatigue by throwing the foot bones "into an oblique position, high behind and low in front. In this position the bones of the foot proper press upon those of the toes, which, in striking in turn against the bottom of their prison, in time become deformed." In the early postwar years physicians regarded the wearing of high heels as sufficiently health-threatening to warrant alerting physical education teachers: "It has been proven when walking in high heels there is a comparative inaction of the muscles of the legs and feet. This results in less perfect circulation through the legs and feet" (77, p. 64).

The *Ladies Home Journal* returned to the issue in 1920, publishing a scientifically oriented article by a female physician, who added charts and pictures of

feet to X-ray photographs to underscore the impact of high heels on equilibrium (78). Dr. Charlotte West observed: "The exaggeratedly high heels now being worn by young girls and all women within the ages of sixteen to forty-five is . . . a matter for serious concern to those having the health of this and the future generation at heart." Indeed, if the narrow and high-heeled boot "were forced upon young girls as a means of punishment we would regard the treatment as barbarous." In order to maintain equilibrium while wearing high heels (78):

> The muscles of the calves are strained; the lower portion of the spine is rapidly held forward; the whole pelvis is indeed shoved forward to get in the new false line which falls through the heels and not through the balls of the feet. An ugly hollow is thereby created in the spine, and when this goes on, as it does in some girls, the distressing spinal deformity known as 'lordosis' is gradually developed.

Finally, West concluded, high heels were such a hindrance to walking correctly that women were not only "deprived of much of the joy in life," but became so fatigued that they walked little or not at all (78).

By the late 1920s, *Hygeia*, a popular health magazine, was publishing frequent reports on high heels. A medical study of the students at a women's college revealed a pointed correlation between normal feet and nonwearing of high heels on the one hand and backache and frequent wearing of them on the other (79). The *American Journal of Public Health* published a similar piece about high school girls (80). A surgeon at the University of Pennsylvania reported in 1928 that 80 percent of the patients with a certain type of ankle fracture were women who wore high heels (81). The etiology was clear: when women used them daily, "the continually maintained hyperextension of the foot is bound to result in a tense and chronically weakened condition of the anterior ligaments supporting the ankle-joint." Any twist of the ankle or fall on a stair—the likelihood of which is itself presumably increased by wearing high heels—then resulted in a sprain-fracture. From the 1930s on, medical texts consistently warned: "High-heeled shoes, if worn for long periods, lead to serious changes in body mechanics and in the alignment of the foot" (82, pp. 295–296).

R. Plato Schwartz and colleagues (83) were the first investigators to apply modern quantitative techniques to evaluate the effects of heel height on gait. In their 1935 article "The Influence of the Shoe on Gait as Recorded by the Electrobasograph and Slow-motion Moving Pictures," they reported temporal and spatial information on three defined foot regions during walking. Simultaneously, a motor-driven camera recorded two-dimensional kinematic information against a defined background grid. In this study and a similar study on heel height published the previous year by the same authors, they observed heel elevation to be partially responsible for instability during gait. In particular, they noted intermittent decreased weight bearing under the fifth metatarsal head with

the use of high-heeled shoes. The inconstant nature of these findings, however, led the authors to conclude that "even a heel two and seven-eighths inches high may be worn upon occasion without subjective discomfort or recordable indication of instability of the feet" (83). To some extent this view persists today, and many physicians contend there is no harm with this intermittent form of shoewear practice.

In the 1960s, the evaluation of gait using electrogoniometers fastened to the body emerged as the standard kinematic analysis technique. Using this approach, investigators at Springfield College performed a series of studies on the effects of high heels (84, 85). They strapped potentiometers on the surface of the skin at the level of the knee, ankle, and subtalar joint. For subjects using moderately high heels (2.5 to 4 inches), the investigators observed surprisingly little effect at the level of the knee (85). Only during the weight acceptance phase of stance were these changes statistically significant, accounting for an average 5 degree decrease in knee extension during walking. Similarly, during running the amplitude and motion of the knee were reduced somewhat. In standing, high heels had no consistent effect on knee angle. As expected, high-heel use shifted the dorsiplantar flexion arc in the direction of plantar flexion according to the height of the heel (85).

At the level of the subtalar joint, the findings of electrogoniometric investigations (84) were generally consistent with those from the more primitive electrobasograph reported 30 years earlier by Schwartz and colleagues (83). The foot remained in supination when walking in high heels throughout the support phase of gait. Similarly, compared with the barefoot condition, out-toeing was less with high-heeled shoes, and step length was shorter. Approximately half of the subjects showed instability while walking in high-heeled shoes. A notable limitation of this study was that the subjects were college students who were occasional, not habitual, wearers of high-heeled shoes.

A similar study was performed by Merrifield (86), who used footprint analysis to assess gait patterns of female college students. In subjects wearing shoes with moderately high heels (2.5 to 3 inches) he observed decreased stride length and decreased step length, but no change in the amount of in-toeing or out-toeing. The use of high heels required that walking be modified by shorter, quicker steps. Further, electrogoniometric analysis synchronized to gait video recordings by Gehlsen and colleagues (87) has explained this gait alteration on the basis of a decreased range of knee motion during the swing phase of walking.

The effects of increasing heel height on spinal orientation have been a matter of considerable interest since the time of the early 18th century physicians Andry (16) and Camper (17). The sagittal plane orientation of the spine has been evaluated with a three-dimensional electrogoniometer while subjects stood on a 2 inch high inclined wooden platform. With subjects in this position, Franklin and colleagues (88) reported a significant decrease in the anterior pelvic tilt, sacral base angle, and lumbar lordosis. However, the changes were rather modest,

averaging approximately 1 degree for pelvic tilt, 6 degrees for sacral base angle, and 3 degrees for lumbar lordosis. The strength of these findings lies in the highly reproducible nature of the recordings from a sensitive three-dimensional electrogoniometer, but the method is limited by the nondynamic nature of the testing protocol.

The kinematic characterization of gait has been tremendously advanced by the development of microcomputer technology and accurate remote-sensing techniques. These technologies were first applied in a systematic fashion to study women's gait by Murray and coworkers (89) as part of a large effort to characterize normal human walking patterns. Using heel heights ranging from 2.75 to 3.75 inches in 30 normal female subjects, they found that the velocity of free-speed walking was decreased approximately 10 percent due to an equivalent stride length reduction. When the women were asked to walk as fast as possible, the average stride length increased to that seen with free-speed (low-heeled) walking. However, it still remained 13 percent shorter than the average stride length of women wearing low-heeled shoes while walking as fast as possible. These authors recorded an average of 4 degrees increase in knee flexion during the stance phase in women wearing high heels. Murray and colleagues thought that this "increased knee flexion during the early stance phase probably provided the mechanism for deploying the mass center of the body anteriorly over the larger and more stable fore part of the foot" (89). Like Gehlsen and coauthors (87), these investigators noted that high-heel use was associated with a diminished arc of knee motion that came exclusively from decreased knee flexion during the swing phase. The findings of Murray and coauthors' study are bolstered by an experimental design that included the gait analysis of 30 normal women evenly stratified between ages 20 and 70 years.

In the past decade, several groups have utilized motion analysis-force platform systems to evaluate high-heeled stance and gait. Opila and colleagues studied subjects standing (90) and walking across a force-sensing platform (91). They reported that high heels caused lumbar flattening rather than the generally expected increased lordosis, commenting that "the change in lumbar lordosis measured in high heeled stance is inconsistent with clinical findings of hyperlordosis in habitual wearers of high heeled shoes" (91). They noted that during gait (91):

> at the pelvis and trunk where exaggerated motions were expected in high heeled gait, no specifically significant differences were found in transverse or frontal plane rotation. An explanation for this may be that the shorter stride length of high heel gait causes the illusion of exaggerated rotations of the pelvis and trunk.

Perhaps this is why Andry (16) and Camper (17) both observed that high heels deformed the spinal column.

Further kinematic analysis by other investigators has generated conflicting evidence on the effects of high heels on lumbar lordosis (92, 93). This led de Lateur and colleagues to ask "If high heeled shoes do not increase lumbar lordosis, why do some patients find that they aggravate back pain?" (92), as had been reported in the medical literature since 1861 (30). They go on to speculate, based on the report of Light and coauthors (94) "who noted changes in skeletal transients on heel strike in normal walking with different foot wear [wherein] resilient heels cut the amplitudes in half [that] perhaps the difficulties resulting from high heels in some cases may result from the hardness of the heel and its resultant shock rather than the height in itself" (92, p. 253). This supposition is consistent with the findings of Snow and Williams (93), who studied the effects of heel height on ground reaction force. They found significant increases in vertical and anterior/posterior forces during walking with higher heels.

Several groups of investigators have taken up the challenge of trying to define the influences of heel height on pedal pressure distribution. As with the kinematic studies, the seminal quantitative work was performed by R. Plato Schwartz and colleagues. Approximately 30 years after his first publication on gait and high heels, in 1964 Schwartz published the first comprehensive quantitative analysis of the distribution of forces under the foot in high heels (95). Using an oscillograph, Schwartz and colleagues studied 86 women in shoes with heel heights of 0.5, 1, and 2 inches. They reported an average 15 percent increase in the forefoot time-force values with an increase from 0.5 to 1 inch heel height, and an average 40 percent increase in the time-force values with an increase from 0.5 to 2 inches. With subjects' use of high heels, Schwartz and coworkers observed an "increased concentration of force at the 1st metatarsal head and the reduction of force over the 5th metatarsal head." Based on his previous electrobasographic and slow-moving picture studies, Schwartz believed that the high-heel-related changes in forefoot weight-bearing patterns could be "accounted for by the increased pronation resulting from instability induced by high heels with small weight bearing surfaces."

In 1985, 20 years after Schwartz and coauthors' publication, Soames and Clark (96) conducted a similar study using small semi-conductor strain gauge transducers secured to the undersurface of subjects' feet. Their findings were consistent with those of Schwartz and coworkers. With increasing heel height, peak pressures under the first and second metatarsal heads increased, while those under the third, fourth, and fifth metatarsal heads decreased. Rasing the heel also reduced the mean peak pressure under the heel and increased pressure under the hallux. Soames and Clark's biomechanical analysis led them to conclude that "with the changed loading conditions associated with increased heel height, greater shear stresses and bending moments are developed in the 1st and 2nd metatarsals and lower shear stresses and bending moments are developed in the 3rd, 4th and 5th metatarsals."

Rebecca Snow and colleagues conducted an analogous study using an optical pedobarograph, with improved spatial resolution (97). Forty-five female subjects

with ages ranging from 22 to 55 years wore shoes with heel heights of 0.75, 2, and 4.25 inches. The sole of the forepart of the shoe was completely removed and replaced with a thin cotton layer. Their findings echoed those of Schwartz and colleagues (95) who had demonstrated a significant transfer of load from the heel to the metatarsal heads with 2 inch heels. However, unlike Schwartz and coauthors (95) and Soames and Clark (96), they did not find a transfer of pressure from the lateral aspect to the medial aspect of the forefoot with the use of high-heeled shoes. Snow and coauthors attributed these differences to differences in the study design, emphasizing that their study used prototypic shoes with a narrow toe box when investigating the effects of increasing heel height.

More than 200 years after Winslow had described the effects of high heels on calf musculature, Joseph and Nightingale (98) performed an electromyographic (EMG) study to quantify these effects. In 1956, they observed that with subjects' in the standing position, high heels caused substantial increases in the activity of the soleus muscle. These authors first conjectured that these increases "might be due to the line of weight being shifted forwards." However, when they measured the line of weight in women wearing high heels they found no constant relationship to this line when the same women wore low heels. Based on this observation they hypothesized that (98):

> in high heels the foot is plantar flexed so that the tendo calcaneus [Achilles] is slackened, and the increased activity detected in the soleus muscle is due to the necessity to take up this 'slack' and at the same time to prevent the body [from] falling forwards at the ankle.

Joseph (99) followed up this standing analysis with a study of the pattern of muscle activity in six women walking in high heels. He identified consistent changes related to the use of high heels, including "(a) continuous but less powerful activity of the tibialis anterior; (b) more powerful activity at the soleus; (c) prolonged, continuous or intermittent, without increased activity in the quadriceps femoris; and (d) an additional phase of activity at the gluteus medius (during the swing phase), gluteus maximus, and erector spinae." He thought that the decreased tibialis anterior activity was due to plantar flexion of the ankle during the swing phase and that this plantar flexion also explained the increased activity of the soleus. He pointed out that "when the foot is plantar flexed, the calf muscles work at a mechanical disadvantage because the line of pull of the calf muscles is nearer the ankle joint." Similar calf musculature findings have been reported by Ono (100) but refuted by Lee and colleagues (101). Indeed, the latter authors found a decrease in gastrocnemius activity with the use of high heels. The disparity of these findings awaits further scientific elucidation.

Joseph (99) thought that the measured increased quadriceps activity in women wearing high heels was due to alterations in the weight-bearing line of the body. He reasoned that since ankle plantar flexion results in the body's center of gravity

being moved anteriorly, knee flexion was necessary to maintain balance. He believed that the increased quadriceps activity was required to stabilize the amount of knee flexion and avoid the tendency to crouch.

The main value of these EMG studies lies in the well-established relationship between median peak EMG activity and muscle fatigue. The effects of high-heeled shoes on overall muscular activity and oxygen consumption have been explored by several investigators. In 1963, Mathews and Wooten (102) analyzed the oxygen consumption of women walking barefoot and in low- and high-heeled shoes. In horizontal walking, the use of a 3 inch heel increased energy consumption an average of 12 percent compared with walking in low-heeled shoes and an average of 18 percent compared with walking barefoot. In 1994, Ebbeling and colleagues (103) reported a similar finding demonstrating a predictable and positive correlation between four parameters of oxygen consumption (heart rate, $\dot{V}o2$, CO_2, and volume) and heel height. These findings are consistent with the observations made by Dowie (30), Jackson (37), and Onimus (47) in the 1860s and 1870s on the fatiguing effects of high-heeled shoes on lower extremity musculature.

Several formal biomechanical models explaining the effects of high heels on the body have been formulated, starting with the work of Norman Lake (104). In his 1949 publication using a two-dimensional trigonometric approach, he estimated that the use of high heels would result in a doubling of forefoot loading with a corresponding decrease in heel loading. In the early 1970s, Steele F. Stewart (105, 106) expanded upon this two-dimensional analysis. He calculated that use of a 3.5 inch heel would result in a 28 percent shortening of forefoot leverage and predicted the resulting ill effects on the forefoot and calf musculature.

A refined two-dimensional, sagittal plane biomechanical model of the forefoot was developed by Stokes and coauthors (107) in 1979 and modified by Wyss and coauthors (108) in 1990. McBride and colleagues (109) applied this approach to determine first metatarsophalangeal joint reaction forces during high-heeled gait. They entered kinematic and force platform data into Wyss and colleagues' model to predict pertinent intersegmental moments and forces. The results of their study demonstrated significant changes in the loading pattern of the first metatarsophalangeal joint during push-off. Specifically, the wearing of high-heeled shoes tended to shift ground reaction forces closer to the first metatarsal head and to double the resultant forces across the first metatarsophalangeal joint.

To summarize, the mechanical effects of wearing high-heeled shoes appear to cause demonstrable changes in gait, pedal pressure distribution, muscular activity, oxygen requirements, and joint loading. The changes in gait include decreased stride length and velocity, less pronation of the foot, decreased range of motion of the knee during the swing phase and increased flexion in early stance, decreased anterior pelvic tilt, decreased sacral base angle, and lumbar lordosis. Modern pedobarographic studies have confirmed Hermann von Meyer's 1858

contention that forces under the forefoot increase with level elevation (29). This increase is concentrated in the medial forefoot with simple heel elevation, but appears to be distributed more evenly across the metatarsal heads with the use of tight-fitting shoes. The body appears to adapt to the unnatural situation of wearing high heels with increased soleus and quadriceps activity. This increased muscle activity is corroborated by evidence from oxygen consumption studies, which have shown significant increases in energy demands with the use of high heels. Finally, sagittal plane mechanical models, developed to quantify the effects of high-heel use on joint loading, predict substantial decreases in foot leverage and increases in metatarsophalangeal joint reaction forces.

In any given individual, the effects of high-heeled shoewear probably depend upon the interplay of many variables including age, weight, ligamentous strength, articular geometry, type of shoe, and duration and intensity of usage. Viscoelastic connective tissue is particularly susceptible to the fatigue effects of repetitive, supranormal loading. In part, the diversity of outcomes from high-heel use reflects the genetic variability in human soft tissue, molecular structure, and anatomical architecture. Clearly, some women have worn high heels for many years without long-term sequelae, whereas others have developed serious foot deformities with short-term use. This diversity of consequences makes it difficult to predict the outcome of elevated heel use for a specific person. Consequently, the institution of mandatory work rules requiring female employees to wear high-heeled shoes—such as those enforced by most major U.S. airlines (110, pp. 308–312)—should be challenged by the medical community. Dudley Morton recognized this need in the midst of the Great Depression (111, p. 174):

> the reason why women are so prone to common types of foot disorder is not the high heel itself, but the continuous use of the high heel. . . . High-heeled shoes are to be regarded as a powerful and vicious factor in the development of foot disorder when worn during working hours. The restriction of their use to evening hours would very nearly eliminate their baneful influence in producing foot disorder.

Despite the medical profession's long history of railing against the use of high heels and the mounting quantitative data documenting the resultant ill effects, much work still needs to be done to change public health perceptions. Although scientists have documented the abnormal mechanical and physiological effects of high-heel usage, they have conducted no full-scale epidemiological studies evaluating the long-term effects of wearing high-heeled shoes on a population of women. The lack of population-based studies is probably the main reason why persuasive information on the harmful effects of high heels has not been widely disseminated.

An analogy to tobacco use can be made. Despite ample laboratory evidence indicating that tobacco exposure caused health problems, not until large

epidemiological studies were performed demonstrating increased cancer rates, lung problems, and heart disease did the general public become aware of the dangers of smoking cigarettes. To argue convincingly against high-heel use and, especially, employer-mandated minimum heel-height requirements, the medical profession must undertake large-scale epidemiological studies similar to those that demonstrated the long-term ill effects of tobacco use. For more than 200 years, doctors have perceived the use of high-heeled shoes as a public health problem (112). The time is ripe to educate government, employers, and the public: standing and walking "perpetually on tip-toe . . . is the death-knell of health and comfort to millions of human beings" (113, p. 466).

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