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**FIREWALKING**

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**When fellow Podiatrist Bill Liggins set out to walk across a BBQ in 2011, naturally he felt it important to share his experience with others. Depending upon your frame of mind, would you follow in his footsteps? Read on to find more about this fascinating topic and activity. Of course this was all in a good cause. Thanks for sharing your experience with ConsultingFootPain and Clinician Portal. This article has been reproduced from an original paper by the author.**

# **Introduction**

All animals possess a natural instinct to avoid fire. This is no less the case with man, or homo sapiens than any other animal, despite the latter’s ability to control the energy and therefore make use of it to some extent. ‘Fire-walking’ in this context, is defined as ‘the practice of walking barefoot over something such as hot stones or wood ashes, often as part of a traditional ceremony’ (1) and is therefore generally perceived as ‘unnatural’ or at very best, a demonstration of ‘magical’ or religious fervour.

The practice has existed since before recorded time and has been widespread across the globe. The IKung Bushmen of the Kalahari Desert use the technique as a part of their healing ceremonies whilst amongst others, clans in the Fijian Islands, girls in Bali and fakirs in India demonstrate their apparent resistance to pain by the assumption of a trance like state followed by a walk across hot stones or fiery embers.(2) The practice is often seen as a rite of passage, or a test of courage although there is frequently a religious connotation and may well be accompanied by the release of the neuro-transmitters dopamine and serotonin. These chemicals have been noted to be associated with transcendent religious experiences.

There are a number of well proven physical facts which demonstrate how the apparently ‘magical’ feat is achieved

Followers of Hinduism celebrate the Thimithi Festival by walking on hot coals to venerate the Goddess Draupadi who walked across fire to prove her fidelity. Japanese Taoists use fire-walking as a method of demonstrating their self-mastery and spiritual advancement.(3) The followers of the Shia sect of Islam walk over fire on the 9th and 10th days of Muharram (the first month of the Islamic calendar) to mourn the death of Hussain – the son of Hazrat Ali and Sayyeda Fatima (the Daughter of Mohammed), although many followers of Islam do not feel it appropriate to mourn too deeply as Hussain is blessed.(4)

In Europe, Virgil writes of Arrun’s prayer to Apollo in which walking on glowing coals is mentioned.(5) Estinarstvo and Anastenária are respectively the Bulgarian and Greek Orthodox Christian fire-walking rituals which are performed in villages in the Strandzha Mountains in the southeast of Bulgaria and Greece. They are performed on the day of Saints Constantine and Helen or the day of the individual village's patron saint. The ritual is a unique mixture of Eastern Orthodox beliefs and older pagan traditions from the Strandzha area. The head ‘nestinar’ may traditionally be succeeded only by his or her son or daughter, and only when he or she is too old or ill to continue performing the ritual. After sunset, the villagers build up a large fire and dance a horo (a traditional round dance) until the fire dies and only embers remain. The Nestinari's barefoot dance on embers then follows. It is popularly thought that some of the dancers reach a religious state of trance while dancing, explaining why their feet do not burn and they allegedly do not feel pain.(6)

Over the past 30-40 years a number of organisations have offered fire-walking as one of a range of techniques to build self-confidence in the individual and as team-building within businesses. Some companies claim to offer such techniques as glass-walking and fire-walking as alternative health therapies and claim that ‘mind over matter’ or ‘spiritual energy’ is a required element to successfully undertake the walk, for example:

“**The first method can be a test whether the belief in the numinous is powerful and strong enough. The second way is a test on the willpower, the third tests the abilities of imagination and magical discipline, the fourth the ‘Neither-Neither’ state of mind.  You can get burnings during a fire-walk, in spite of contrary statements by physicists. Do not forget this (I am sure, this won't happen). The cleansing power of the fire spirits can do minimal burnings at certain reflex zones at the feet, activating these points on this way.”(7)**

**Clearly, the number of perfectly** respectable companies involved in team building without the benefit of being imbued with feelings of divinity, who have no ‘magical discipline’ and who do not claim to be possessed by ‘the cleansing power of the fire spirits’ tends to debunk such questionable statements!

There are a number of well proven physical facts which demonstrate how the apparently ‘magical’ feat is achieved; however anatomy and physiology are rarely mentioned. The first recorded scientific investigation in the West was carried out by Harry Price of the University of London Council for Psychical Research in 1935. The examination of the phenomenon was carried out at Carlshalton in Surrey when Mr Kuda Bux, a Kashmiri ‘magician’ who was under examination for an unrelated ability, mentioned that he had the ability to fire-walk and was willing to demonstrate how it was done. In this case charcoal was added to a previously prepared oak wood fire. Unfortunately, no podiatrist was present but the feet of Kuda Bux were examined by a medical practitioner who was convinced that no form of chemical had been applied to the plantar surface of the feet which were ‘soft and dry.(8)

Bux walked across the glowing charcoal four times without any sign of pain, and when his feet were afterward examined, there was no evidence of damage. A Mr. Digby Moynahan who also attempted the walk jumped off the charcoal after two steps demonstrated some blistering. An extant photograph shows that Moynahan was lifting the opposite leg very high. This would result in the weight bearing foot being driven more deeply into the coals, and more importantly, for a longer period of contact. A later investigation carried out by the same body with different volunteers, a Moslem named Mr Ahmed Hussain and an Englishman, Mr Reginald Adcock resulted in no adverse effects to the surface tissues. The Council concluded that the low thermal conductivity of the burning wood and the brief time of contact between the feet and the coals offered the most likely explanation. (9)

Heat can be transmitted in three ways, by radiation, by convection and by conduction. Radiation is an electromagnetic wave of infrared energy and does not require contact between the irradiated body and the source of energy. A good example is the heat of the sun’s rays reaching the planet Earth. During a fire-walk, little radiation reaches the feet because of the relatively short length of time of the walk itself. Spectators in the region of the fire may experience far more heat on their faces because of the longer period they are subject to the radiation coupled with the higher sensitivity of the face to heat. This, in turn makes the performance appear even more impressive. Convection occurs when the excited, and hence less dense molecules of a gas, are displaced by the cooler and denser molecules (hot air rises). In the case of fire-walking, the gases held in the wood are all driven off by the initial burning, and charcoal is made by burning off the gases whilst excluding oxygen. There is therefore, little or no gas to be concerned about in the glowing coals during a fire-walk. Conduction is the transmission of heat by direct contact and is the most relevant form of energy transmission in this context. Energy is transferred from molecules having higher levels of energy – *the coals*, to those with lower energy – *the plantar surface of the feet* *-* in an attempt to bring about equilibrium.(9)

As noted by Price, the thermal conductivity of wood is low.The thermal conductivity of charcoal as used in the Carlshalton experiment is even lower and the brief contact of the foot with the coals allows little time for heat conduction. In addition, the larger the surface area of conduction, the less the conduction at a specific point on that surface area. It should be noted that the thermal conductivity of most metals is thousands of times higher than that of wood or charcoal, and despite claims to the contrary there is no evidence of any individual walking on red hot metal without injury. It has been suggested that the Leidenfrost effect may be an explanation for the phenomenon of burn free fire-walking.(10)

Johann Gottlob Liedenfrost investigated the effect extensively and published “A Tract About Some Qualities of Common Water” in 1765. The term describes the vaporisation of the surface molecules of water without the energy being immediately transferred to the water as a whole. This is commonly seen when a water droplet ‘sizzles’ on a pan heated to beyond the boiling point of water (1000C). The surface of the water in contact with the pan vaporises causing the droplet to move about rapidly. The thermal conductivity of water vapour is much lower than that of water and since the hotter the temperature of the pan, the smaller the contact surface of the water, the anti-intuitive situation occurs that the hotter the pan, the longer the droplet takes to disappear through radiation and slow conduction. Even more commonly, an individual ironing clothing will lick a finger and briefly apply it to test the hot surface of the iron. If the iron is sufficiently hot, the water on the finger will vaporise resulting in a ‘sizzle’ but the finger will remain uninjured. The effect was harnessed by nineteenth century ‘magicians’ who dipped their hand into vats of boiling lead without suffering ill effects. This feat was nobly repeated by Jearl Walker at Cleveland State University who also carried out several fire-walks.(11)

A thirteen feet by three feet trench was dug and filled with hard wood cuttings and chippings

In a healthy person the normal body temperature is maintained at 370C by the thermoregulatory centre in the hypothalamus. Heat is lost through the skin by means of vasodilation of the blood vessels and sweating. The plantar surface of the foot is well supplied with arteries, arterioles, veins and venules. The plantar and palmar skin differs in many respects from the skin on the remainder of the body including the number of nerve endings and the number of sweat pores, the latter in the epidermis. These in turn are served by a complex plexus of capillaries which unite to form the arteries and veins noted above and are capable of rapid and profound dilation when subject to high temperature gradients. The additional sweat glands in the dermis produce sweat which forms a thin layer over the surface of the epidermis to enhance grip. The normal stratum corneum on the plantar surface is up to fourteen times thicker than that on the remainder of the body and this can increase in pathological cases of callosity.

# **The author attended a fire-walk**

This was carried out for the charity **The Mary Ann Evans Hospice** and the walkers had all gained sponsorship for the event. The only commonality of the walkers was a desire to benefit the charity and a willingness to carry out the challenge, otherwise they were drawn from various employments and many were previously unknown to each other. The organising company (14) ensured that a fully equipped firefighter was on hand and that the area of the fire-walk was suitably roped off from the numerous spectators. The site of the walk was an area of grassland with ample room for movement.

A thirteen feet by three feet trench was dug and filled with hard wood cuttings and chippings which were then set ablaze in the afternoon preceding the walk. Buckets of cold water were placed about two feet away from the end of the trench where the walkers would complete their challenge. At nineteen-thirty hours, the walkers met with the organiser who took them through a careful briefing with demonstrations which showed that, with self-confidence, seemingly impossible tasks can be carried out with aplomb. Forms of disclaimer were signed and the walkers checked to ensure that no moisturising or other cream had been applied to the feet.

A recording of a piece of burned, ash covered charcoal provided a temperature of 276.70C (531.10 F)

The participants were instructed to walk steadily over the coals and to plunge their feet into the cold water after completing the challenge in order to douse any cinders attaching to the feet. Towards dusk the fire, which had burned to embers, was checked; large pieces of wood were removed and the embers flattened. Although the walkers were clearly motivated, it seemed that the spectators were more excited by the prospect of observing ‘the impossible’. Despite the fact that dusk had fallen – which made the glowing coals all the more impressive – there was no dew apparent on the grass. An infra-red digital thermometer was used to measure the temperature of the fire pit at 5230C (973.40F).

For comparison, a domestic barbecue (used to cook beef steak and pork sausage) measured 5070C (944.60F) at the hottest portion of the burning charcoal (temperature taken on 3rd August 2011; a still, warm evening). A recording of a piece of burned, ash covered charcoal provided a temperature of 276.70C (531.10 F). The organiser checked the fire and carried out the initial walk himself. He was followed by the rest of the twenty walkers, none of whom refused to carry out the challenge. Three of the walkers volunteered to have the temperature of their feet measured before and after the experience, prior to using the cold water. The results are shown in the table below.

|  |  |  |
| --- | --- | --- |
| Volunteer number | Temperature of plantar surface of right foot immediately prior to fire-walk (degrees centigrade) | Temperature of plantar surface of right foot immediately following fire-walk (degrees centigrade) |
| One | 28.9 | 33.5 |
| Two | 24.9 | 27.9 |
| Three | 28.6 | 30.5 |

It seems therefore that the temperature rise of the feet of the three volunteers, although obviously meaningless for statistical purposes, does suggest an increase of only two to three degrees centigrade after being subject to a measured heat of 5230C for four steps. Clearly, dilation of the plantar vessels must have been profound and nearly instantaneous.

Anecdotally, in conversation with the walkers following the event, the majority stated that their feet tingled but that they did not experience heat from the fire pit until the end of the walk. Three of the twenty felt ‘burned’ and developed small blisters. It was notable that these people were rather anxious and walked very rapidly. Although initially reluctant, since the author had not attended the motivational discussion, the organiser was courteous enough to allow him to carry out the walk, having been convinced that he understood some of the physics underlying the experience:

“The grass was cool, but not damp. The fire was still radiating considerable heat and was glowing brightly, although a thin layer of ash overlay the coals. I took the first step from the grass with my knees slightly in flexion, thus limiting heel strike. The coals felt a little warm to the foot but definitely not hot. The sensation was akin to walking on a fairly deep layer of broken biscuits or potato crisps. I took a further three steps in a similar fashion, trying to present the largest possible surface area of the foot to the fire and moving calmly but reasonably briskly in such a way as to avoid pronounced heel strike and toe off. I am convinced that I could easily have carried out a walk of double the length without overt tissue damage.

After stepping off the fire, the plantar surfaces of both feet were covered in a fine layer of ash which required washing off later. Some of the hairs on the lower portion of the leg were singed. In common with others of the walkers, I experienced some warmth and tingling of both feet but no pain at all. On the following day, four areas of hyperaemia of circa 1mm diameter were noted on the plantar surface of the left foot, just proximal to the 2nd metatarsal head area, and three similar discolorations in precisely the same position on the right foot, both being proximal to the weight bearing areas. These were painless and could not, therefore be classified even as first degree burns. The epidermis thickened slightly in these areas and was shed with the normal skin squames over a period of three weeks. There have been no long term effects.”

# **Conclusion**

In analysing the outcomes of the fire-walk, it should be noted that the walkers, having experienced the motivational talk, and being slightly anxious, were variously affected with an ‘adrenaline rush’. Their hearts were pumping faster with a resulting increase in blood flow to the feet. Although this produced increased sweating, the fine layer of ash thus adhering to the feet would have added insulation and prevented epidermal contact with the fire. It seems highly unlikely therefore that the Leidenfrost effect had any bearing on the lack of damage to the tissues. In addition, Bux experienced no damage, although his feet were quite dry (since he had wide knowledge of fire-walking, it is a reasonable assumption that he experienced no particular increase in adrenaline and hence no sweating). The poor thermal conductivity of wood and charcoal has been cited as the major factor in the lack of tissue damage to the foot. However, it seems that there are other reasons which were not noted by Price in his original experiments:

1. the pressure of the cooler body (the foot) on the hotter body (the coal) will result in the hotter body losing heat rapidly
2. water (blood, tissue fluid) has a high thermal conductivity whilst the coal has much less
3. the layer of ash adhering to the foot acts as an effective insulator
4. placement of the feet in such a way that the maximum area of the foot is in contact with the coals reduces the possibility of the heel and the metatarsals ‘digging in’ to the deeper, and hence hotter, areas of the coal. Running, or walking too fast will result in blistering
5. walking firmly but briskly across the coals reduces the contact time between the feet and the charcoal
6. the complex venous plexus on the plantar surface of the foot, and the rapid dilation of the vessels when subject to heat results in very effective local cooling and prevents the tissues from reaching the temperature that burning will take place
7. the thick stratum corneum on the plantar surface of the foot offers insulation. Callous might increase resistance to burning to some extent and the ‘tougher’ plantar surfaces of peoples who are generally unshod may offer increased protection

Historically, the individuals carrying out fire-walks have been regarded as ‘special’, either with regard to courage or religious fervour. However, it seems that any normally fit and motivated person can successfully complete a short fire-walk without ill effects. Motivation is the key. The author was told by a firewalker that she suffered from two ‘phobias’. One was fire and the other heights. Having completed the fire-walk she intended signing the next day for a sponsored parachute jump. Needless to say, the process is not a good subject for do-it-yourself; the proper wood must be used and health and safety demands that certain rules are adhered to.

The final word must go to Jearl Walker, who as a physicist can be forgiven for overlooking the obviously important biological element:-

“I have long argued that degree-granting programmes should employ ‘fire-walking’ as a last exam. The chairperson of the programme should wait on the far side of a bed of red-hot coals while a degree candidate is forced to walk over the coals. If the candidate’s belief in physics (anatomy and physiology [*author*]) is strong enough that the feet are left undamaged, the chairperson hands the candidate a graduation certificate. The test would be more revealing than traditional final exams.”

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