

Understanding feet

How much do you really know about feet other than they are the oddly shaped things attached to the bottom of legs that help you to move around? Most people don't know very much and do not care until the day something starts to go wrong.

The foot is in fact a highly efficient mechanism which uses energy from the body to power the muscles and levers that allow us to perform a range of complex functions.

It is also extremely complicated, containing no less than 26 bones joined by 107 ligaments and linked to 19 muscles by a series of tendons in order to create movement. In addition, there are nerves that link it to the brain which tells it what to do and blood vessels that carry the minerals and proteins

that maintain the tissues protecting the central bone structure.

Understanding how this complex structure operates is an essential element in shoemaking. Unfortunately, too many shoes are still produced that ignore fundamental principles and this, coupled with consumers buying shoes that clearly do not fit, is why so many people have foot problems. It is particularly true where women are concerned who, when young, are far more concerned with appearances than comfort. The balance between the anatomical demands of feet and those of fashion has long been a headache for shoemakers.

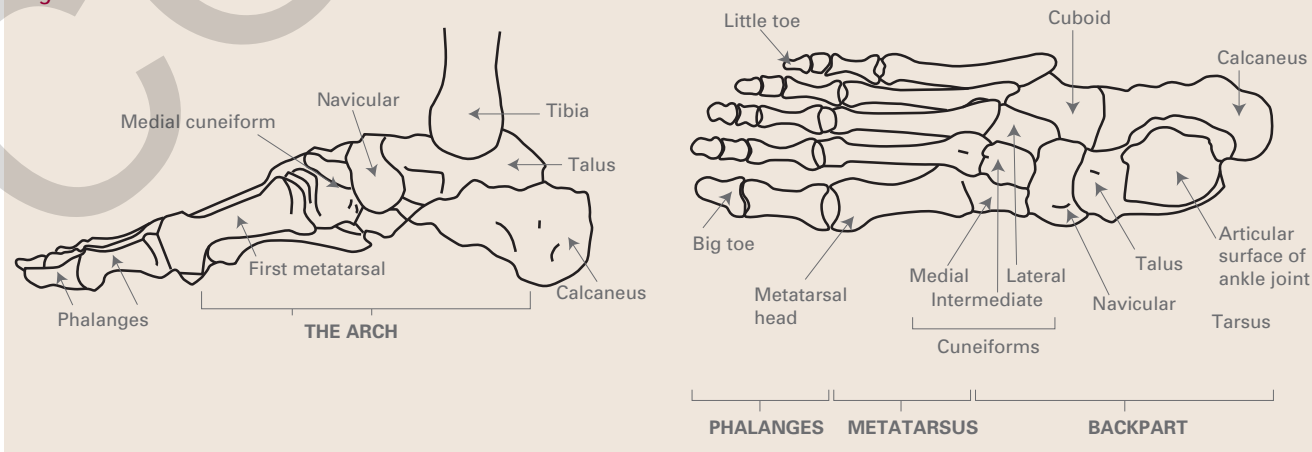
FEET AND BONES

The bone structure of the foot is divided into three groups (*Figure 1*);

Tarsus with seven bones including the calcaneum or heel bone, Metatarsus with five bones and comprising the middle of the foot and Phalanges with 14 bones which make up the toes. The bone itself is formed by the deposit of calcium phosphate which forms a strong, light, honeycombed structure.

This is a long process which continues into the late teens. Children's feet therefore have little real structure and cannot detect any discomfort resulting from pressure, so correctly designed lasts and carefully fitted shoes are essential if deformities are to be prevented. They are at their most sensitive between the ages of 9 and 12 months when children take their first tentative steps. Once walking is mastered, they begin to run around learning about the world around them.

Figure 1 - Bones of the foot.



It is therefore vital that their shoes do not hinder this key stage of development in any way.

Furthermore, the feet are growing and, because the bones are only partially calcified, this places certain constraints on the shoe. While it cannot be too tight, it must nevertheless still offer protection in terms of support to the anklebone for children aged from one to three. Although very few children are born with malformed lower limbs, only some 40% of adults have healthy feet and this is mainly due to wearing inappropriate shoes during childhood. Once the damage has been done, it cannot be undone, so the accurate fitting of children's shoes cannot be over emphasised.

The bone structure also forms two arches. The longitudinal arch falls

between the heel bone and the head of the first metatarsal. Its height varies from person to person and its absence on some is the cause of flat feet and many other foot problems. The height also varies ethnically, with Italians and Japanese, for example, tending to have particularly high arches and insteps. Beyond the age of 80, the foot becomes more flexible and the arch much weaker. The transverse arch lies across the base of the metatarsals when the foot is relaxed. Under load, it flattens out and the foot becomes wider as the bones spread.

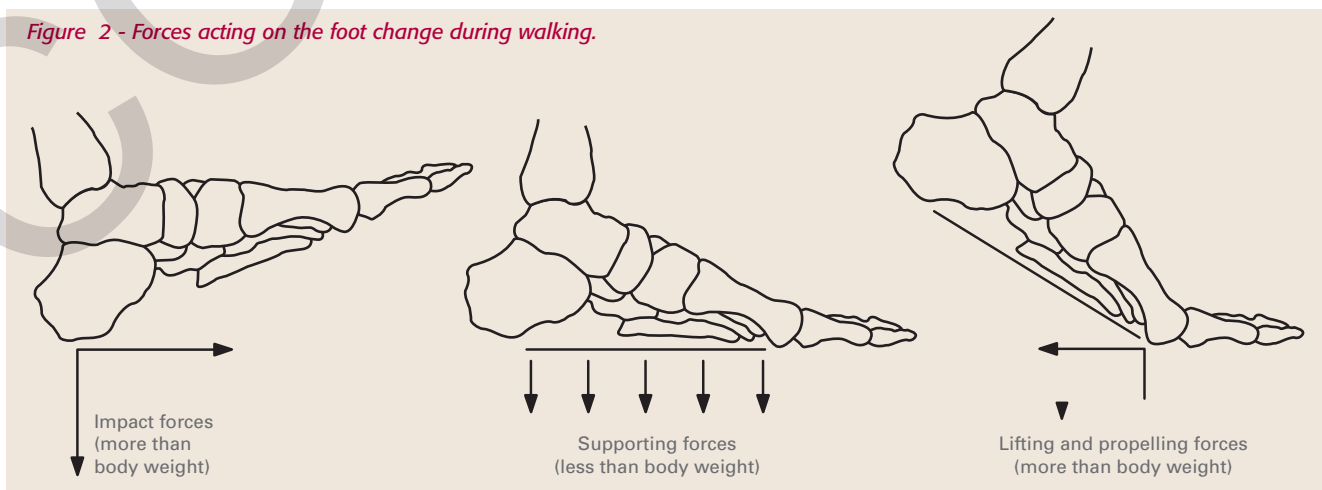
GAIT

When walking, our feet have to support the body and, at the same time, provide propulsion to move it forward. They work in a rolling fashion where

the outside of the heel hits the ground first, the forefoot contracts, the foot rolls inwards and the point of greatest pressure follows the outer edge of the foot up to the outer joint. As the heel lifts to flex the foot, the pressure is transferred over to the inner joint and thence to the big toe. This then acts as a lever to propel the body forward. It is also why it is so difficult to walk with a damaged or missing big toe.

An average day may involve up to 10,000 steps and the transmission of surprisingly large forces through very delicate and fragile areas. Excessively long periods of standing or running, jumping and walking on uneven surfaces can therefore create problems particularly if a person is overweight. When walking, feet come under the impact of one and quarter times body

Figure 2 - Forces acting on the foot change during walking.



weight, so extra weight means ankles, bones and joints in the feet are under increased pressure (Figure 2). They also need to provide more shock absorption for the body. That in turn means more wear and tear and a greater likelihood of foot or ankle pain. In addition, the bones of the foot are held together by ligaments, so extra weight can force the joints apart and make these ligaments stretch. This can change the shape of the foot so that it starts to splay, become wider and the arches to begin to collapse.

SHOES

Footwear should be functional in order to work with the foot rather than against it. Although this might appear to be common sense, fashion all too often tries to ignore this fundamental truth leading to lasts and the shoes made on them to cause considerable harm to people's feet (Figure 3). It is therefore essential that as well as providing good fit and comfort, a shoe must cause as little disruption to foot function as possible.

A factor that few people seem to be aware of is the degree to which feet can change shape and size during the course of the day, expanding in girth by over one and even up to two sizes. There is no way that a relatively static object like a shoe can adapt itself to keep up with the dynamics of the human foot from early morning to last thing at night, so the best time to buy a pair of new shoes in terms of fit is in the afternoon.

Needless to say, it is the last shape that is the key factor here and should therefore take into account the type of person who will wear the finished shoe and the purpose for which it will be worn. Sports shoes, for instance, require a different set of parameters to dress shoes as do children's to adults and men's to women's. In addition, today's global market means that lasts must also vary in order to fit a wide range of ethnically diverse feet as these vary physically in both size and shape across the world as indeed do their owners.

LASTS

Previously shoemakers would measure a person's feet for the handmade shoe and make a pair of lasts to match so that the shoes made



Figure 3 – Too tight a fit on a pointed toe can distort the foot leading to health problems in later life.

CREDIT: SATRA

on them were a good fit. While today's last makers have to make compromises for mass production, they must nevertheless still take into account the mechanics of the foot to ensure the shoes that will be made on their lasts are functional as well as aesthetically pleasing. While the design of shoe lasts is highly complex, there are some basic facts that apply to any last and govern its relationship with the foot:

The last needs to be longer to allow for elongation under pressure. This will vary with the weight of the person concerned and the physical condition of their feet. For instance, a weak foot will elongate more than a well-developed one and a child's less than an adult's. The foot also tends to move forward in walking regardless of fit, so in the case of narrow-toed lasts extra length is also needed to prevent pressure on the toes as seen in Figure 3. Many women still refuse to acknowledge the actual size of their feet and buy shoes a half or even a full size smaller just so that their feet also look smaller. It is why so many suffer from corns and even more serious foot problems such as bunions.

A normal last will not reproduce any

of the foot's irregularities as this would look unappealing and also cause manufacturing problems. The exception occurs with orthopaedic footwear where physical deformities must be accommodated by special lasts and hand lasting (Figure 4).

When placed on a level surface to the correct heel height, the toe should be raised. This is called 'toe spring' and is essential in helping the rolling motion of the foot and preventing undue creasing across the top of the shoe. Finally, the top or 'cone' of a last is narrower than the foot itself. This is because the sides of the quarters are not held together in any way and this narrowness prevents gaping when the shoe is worn.

While a last's border outline corresponds fairly well with that of the foot—except at the toe—it is straighter and the inside joint position further forward. The former allows for a natural inward turning of the big toe when the heel's height or 'pitch' is increased and the latter is because the foot's contact point with the ground also moves forward as heel height increases. The bottom shape is also different due to a last having a defined 'feather' edge whereas the foot is rounded.

HEELS

Heel height has a marked impact on foot function. When standing or walking barefoot (our natural condition), more of the body's weight is taken by the heel than the forefoot. As the heel is raised, so more weight is progressively transferred to the forefoot and also influencing the way we stand and walk.

In its normal state, the foot bends some 50 degrees during the 'take-off' phase of walking. If the shoe restricts this by being too stiff, it causes discomfort and fatigue. This can be offset to some degree by adding more toe spring. However, if the heel is high, less toe spring is needed as the foot is already partially flexed and, in general, the higher the heel the less the toe spring. If a high heel is matched to a platform forepart, the latter must have extra toe spring built into the platform itself in order to restore sufficient rolling motion. Similarly, in sports or casual footwear with thick soles, sufficient toe spring must again be included.

A high heel is considered to be one that raises the back of the foot above the metatarsus and phalanges. The degree of height depends on the height of the heel and the pitch of the last. Typically, a high heel is raised more than 5cm, causing the metatarsals to slant towards the phalanges at an angle of between 40 and 55 degrees. Without exception, they are bad for the feet and the cause of many problems, including pain in the toes and balls of the foot, ankle instability, and pain in the muscles of the legs and lower back. Almost 85% of women list one or more of these as a regular occurrence with high-heeled shoes.

The reason for all this can be easily explained. The standard high-heeled shoe construction creates an angle of the heel seat to the ground surface referred to as heel pitch or wedge angle. This creates a ramp effect so that the foot slides forward into the toe which, if narrow, prevents this forward motion and so creates continuous pressure on the toes. Extra pressure is also applied to the metatarsal heads, particularly the second and longest metatarsal. Studies have shown that women who go from flat athletic type shoes to ones with 5cm heels undergo nearly 64% increased pressure to the forepart of the foot. In addition, while the ideal normal barefoot distribution is 50/50 between forepart and heel, exaggerated 75cm plus heels change this dynamic to nearer 80/20 towards the forepart thus exacerbating the situation.

FEET AND RESPONSIBILITY

The foot is clearly a highly complex mechanism and properly manufactured and correctly fitting footwear is a vital factor in our everyday comfort and long-term health. Anyone involved in the specifying, sourcing and manufacture of footwear for the global market should therefore do their utmost to ensure the lasts used in the manufacture of the shoes involved are suitably modelled to permit proper functioning of the foot during the end use for which they are intended. There are several testing and research organisations such as SATRA, CTC and PFI which have extensive data on national foot fitting characteristics, so there is really no excuse for badly fitting lasts. 🚫



Figure 4 – Hand lasted orthopaedic shoes for a customer with badly twisted feet.

CREDIT: JANE SAUNDERS & MANNING

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