During the past few centuries we have seen considerable changes in the types of ground on which we walk. Surfaces have changed from natural, soft, undulating ground to synthetic, hard, flat surfaces. This has had a significant influence on the foot’s mechanism for dampening impact and rigid propelling forces. In response to these evolutionary changes, through natural comfort and performance selection, footwear has continued to experiment with different forms of biomechanical criteria.

Although marketing jargon often highlights the benefits of a ‘comfortable environment’ inside footwear, one of the most interesting ‘trends’ in both casual and athletic shoes of late has been the emergence of brands promoting the benefits to the wearer of ‘forefoot technology’—i.e. shoes that place the foot and the body’s centre of gravity on a different plane or position from neutral to 10° to 15° plantar-flexed, thus concentrating on the interaction between the footwear and the surface on which it is worn.

Forefoot technologies come to the fore

In its most natural and basic form—namely, moving barefoot on flat earth or sand—walking is surprisingly efficient through the natural optimisation of energy transferral and minimising the displacement of the centre of gravity. The initial contact between the foot and the ground—which is the beginning of the loading response—is still referred to as ‘heel strike’. Concentrating on the sagittal plane during the walking pattern, the normal barefoot strike at the beginning of the loading response is at the heel with the foot in a dorsi-flexed position.

Footwear in its earliest form, the sandal and the moccasin, was relatively flat, thus allowing the walking foot to strike at the heel with little difference. However, the term heel strike should be confined to walking, because when running the term ‘foot strike’ is far more appropriate as, even at relatively slow running speeds, many people make initial contact between the shoe and the ground in some region other than the heel or rear part of the shoe. During running the direction of the force generally changes from upward during the footstrike transient to upwards and backwards immediately afterwards. Furthermore, there is considerable variation between individuals as to how much ground force is applied during initial contact, as some people tend to ‘glide’ into the strike, whilst others cause more of a ‘collision’ with the ground.

Friction also plays a vital role and is a prerequisite for locomotion. Friction forces act horizontally in the contact plane between two bodies i.e. the Earth’s surface and the barefoot or shoe. According to a study conducted at the Institute of Sport Sciences in Cologne, Germany, a sliding movement (or dynamic friction) between the foot and ground is undesirable because it reduces the horizontal ground reaction and dissipation of energy. However, static friction opposes the direction of movement and decelerates the relative velocity and is, therefore, required in walking and running.

With so many factors to consider—such as whether footwear is being designed for walking or running, for men or women, for which demographic group i.e. children, adults, and each individual’s personal preferences, gait and requirements—footwear designers have stepped up to the challenge to develop new styles and technologies to meet the demands of the lucrative casual and sports footwear market.

Finding the positives in a negative

Many new or renewed shoe concepts have been introduced into footwear over the past several decades that are conceived and/or marketed as ‘natural’ and one development that is proving popular with several brands, in terms of the interaction between the foot and the
ground, is the inclusion of a negative heel. The Earth shoe has recently been reintroduced into the USA by Earth Footwear Inc. Earth shoes were initially launched over 30 years ago but then disappeared for many years, until their recent resurgence. The company has launched a range of running and walking performance shoes with a 3.7º negatively-inclined heel that is said to “burn more calories to help the wearer lose weight and reduce cellulite”. Earth also claims that as the negative heel corrects posture, it can even relieve chronic back pain, muscular aches and joint problems and positions the foot correctly (within the shoe) for optimum muscle function.

The brainchild of Danish yoga master Anne Kalso, the Earth shoe is made with an anatomical plantar surface with a ‘minus’ or negative heel. This means the rearfoot is positioned slightly lower than the rest of the neutral plane sole surface. This concept is often referred to, both biomechanically and anatomically, as ‘natural’ as the negative heel concept is designed to simulate walking barefoot in soft sand, allowing the heel to sink lower than the mid and forefoot. Anne Kalso conducted studies over a twelve-year period to create and hone the shoe and often embarked on 500-mile treks herself to test the concept. In 1969, an American couple visited Denmark and discovered the technology and took it over to the United States, where the shoes were launched to coincide with the world’s first Earth Summit, and aptly named Earth Shoes. They initially attracted a huge following amongst the hippy community and then gained popularity in the mainstream markets across the USA. And whether the concept is correctly termed ‘natural’ or dorsi-flexed, it does appear to improve the posture of the body allowing the wearer to stand and walk in a more upright position through better alignment of the spine.

Earth has recently ventured into the performance arena with the introduction of the Earth energetic models for men and women. Although to date there has been no biomechanical validation of its claims, Earth believes that its workout shoes offer “natural body alignment and greater endurance”.

Swiss company SpringBoost also produces footwear based on the negative heel ‘dorsi-flexion’ concept with a modular three-set interchangeable insert programme and has carried out serious biomechanical and elite athlete testing on its design. With the foot in a dorsi-flexed position, the heel is again placed lower than the forefoot in a biomechanical principle that has been used by physiotherapists and shoemakers for years in an attempt to reproduce the natural feeling of walking barefoot in sand. Furthermore, Japanese traditional medicine claims that this positioning of the foot enhances the circulation of the blood.

SpringBoost has also gone one step further, by actively testing and producing shoes for competitive athletic use, which has proved successful. According to the company, “The user is placed in a pre-stretch position that results in plyometric work—a type of training that is recognised to increase performance. The posterior muscular chain works at an increased length resulting in a better conditioned muscular efficiency. The body is naturally positioned correctly to execute exercises in an optimal

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Newton Membrane technology replaces the typical foam of modern running shoes. On impact the four active red mid-sole actuator units are driven into chambers in the sole and stretch the membrane. The foot’s forward movement releases the actuators from the chamber and returns the impact energy into forward propulsion.
manner; increasing range of motion of the foot is resulting in a more powerful stride.” And this is not merely a case of elaborate marketing jargon. The company conducted seven years of work with high level athletes and teams. Furthermore, independent institutes such as the Sport Medicine Unit of the Rehabilitation Clinic of SuvaCare in Sion, Switzerland, and the Sport and Health Physiology and Physiopathology lab of the University of St-Etienne, France, have certified the company’s claims that SpringBoost’s Dorsi Technology improves performance in explosive power, vertical leap, speed, and efficiency in muscular work load.

**A scientific twist on nature**

Newton Running, based in the USA, has also developed footwear to mimic ‘natural’ barefoot running, but the company has adopted a very scientific approach to creating ‘natural’ movement. Biomechanically tested, Newton’s membrane technology is located at the forefoot to improve afferent feedback and has been developed for the serious runner, based on the concepts and laboratory testing of eminent researchers such as Benno Nigg, B.De Wit, M.A. Nurse, C. Reinschmidt, D.J. Stefanyshyn, L.N. Burkett and the late Dr. Amy Roberts. All of these experts recognised the differences in the foot-ground interface contact between barefoot running and when wearing footwear—such that the active initiation of the kinetic adaptations just before foot contact is followed by a more passive kinetic interaction between the contacting leg and the ground during the initial contact phase when wearing a shoe. The ‘disadvantages’ are specific to the properties of the athletic shoe when compared with the biomechanical properties of the unshod foot.

The forepart of the foot is the most sensitive area to load-bearing and vibration stimuli. In the barefoot condition the Achilles tendon, the ligaments and arch of the foot have a much greater potential to store energy. Therefore in the unshod condition almost all of the stored energy can be returned to the athlete. In shod running the sensory feedback from cutaneous receptors in the plantar surface are dampened by the cushioned sole of the forefoot portion of the athletic shoe and this results in reduced lower extremity muscular activation patterns.

Taking this into account, Newton placed its Membrane Technology and active units in the forepart of the shoe so that the affect of the technology is centred on the metatarsal heads to develop a shoe that is said to maximise the energy return between the ground, shoe and foot and minimise the energy lost during shock absorption.

Looking to nature and ‘natural walking’ has also inspired another of the latest ‘trends’ in modern footwear to enjoy success in the marketplace. Known by the unusual name of MBT Swiss Masai, this footwear technology was developed by Swiss engineer Karl Müller. MBT was the result of observing the Masai, an East African semi-nomadic tribe, that maintain excellent posture while walking barefoot on soft, natural ground, thus better balancing their bodies with each step. Furthermore, joint and back pains are almost unknown amongst the Masai people who also seem to enjoy stable health and remarkable athletic ability.

Promoted as ‘physiological footwear’, MBT shoes and sandals are marketed as a ‘challenge’ for the whole body, offering a training effect that offers the wearer benefits such as “gait and posture improvements, relief from pressure on the joints and back and firming up muscle activity in the abdomen, back, buttocks, rear thigh and lower limbs… by stimulating the metabolism which leads to weight loss and speeding up regeneration.”

From a biomechanical standpoint, MBT states that one of the human body’s most complex tasks is to remain upright and balanced when walking and standing, which is dependent on a multitude of supporting muscles throughout the body. The company claims that conventional shoes support and lead the foot, stabilising the body in an unnatural way thus leading to important muscles losing their function and
become inactive which can cause them to atrophy, and result in many of the health conditions of modern civilisation, such as joint and back pain. MBT claims to counteract this effect by stimulating the body to balance itself.

The transition motion of the MBT sole substitutes for the ankle, subtalar and metatarsalphalangeal joints going through a full range of sagittal plane motion. The technology responsible for these ‘effects’ is the result of a patented sole structure including the Masai Sensor, the Shank and the PU midsole with pivot (or rocker), which simulate a natural, soft surface to create a ‘natural instability underfoot’. MBT claims this effect stimulates and exercises the body’s supporting muscle system thus triggering a positive reaction on the entire body.

Another new brand launched in 2006 taking the ‘scientific’ forefoot approach, based on the best of nature, is Velocy, based in Portland, USA. Velocy is the brain child of Elliot Michael and design engineer Nick Martushev. Research over a ten-year period included looking at various animal species to identify the factors that allow them to accelerate rapidly and maintain efficiency over extended distances. Humans do not have the means to counterbalance their centre of mass, hence as 100-metre sprinters leave the blocks they can only maintain a forward lean as they accelerate. At 65-70 metres their top speed is achieved and they then have to try to maintain that speed through their muscular ability.

Through its research, Velocy claims to have unlocked nature’s secret to harnessing the force of gravity. Named Forward Gravity, the company’s technology is said to move the centre of mass forward in the direction of movement and emulate the stabilising systems found in animals, such as wings, tails, limbs, and claws, to counterbalance the amount of forward lean necessary to achieve optimal rates of speed and efficiency. Velocy has achieved this effect primarily through a high density TPU (thermo plastic urethane)/nylon 6 glass fibre forepart plate that allows the body to maintain a forward lean angle in the direction of movement. As Velocy states, “This synchronised unit improves body mechanics in relation to foot mechanics and allows humans to achieve greater power, balance and stability, enhancing performance and efficiency while reducing risk of injury.”

A new angle on footwear

Chung-Shi is a patented shoe concept, with a severely angled 15° outsole at the toe and heel of the shoe and is marketed as a ‘Balance-Step’ exercise walking shoe. The design of the sole is said to encourage a soft heel strike with a natural, forward-rolling action, which is further supported and softened by an air pocket cell in the shank area of the sole. The shock attenuation action of walking on hard surfaces is therefore reduced. A further benefit of the 15°-angled sole is said to be that the shoe automatically positions the wearer into a stable, correct walking gait with a shortened stride, leading to more upright, relaxed walking. Similar to the claims made by MBT, Chung-Shi also claims its footwear increases the toning and strengthening of muscles, increases circulation and respiratory function, and improves posture.

Z-Coil’s plantar-flexed shoe technology goes one step further, not only improving posture and circulation, it is said to offer pain relief. Developed by Al Gallegos, a runner who suffered from various common running injuries such as plantar fasciitis, knee pain and back pain, the Z-Coil is said to provide approximately four times more cushioning in the heel area than other types of footwear. This is achieved through a three-inch steel coil spring positioned directly under the calcaneous, which acts as a super shock absorber on heel landing and returns up to 90% of energy on rebound. In order to compensate for the radical heel spring height the shoe is stabilised by a Z-Coil anatomical cradle, which distributes pressure and can be adjusted for over-pronation and supination. Extra forefoot cushioning lessens the plantar-flexed angle of the foot in the shoe and reduces forefoot pressure. It also assists the natural flexing point of the foot with a permanent flex groove across the outsole. Although rarely used for competitive sports activities, runners and wearers suffering from heel pain, joint pain and other intractable pain agree that the shoe does what it claims.

Another concept—which is not yet on the market—is set to take forefoot technology to a whole new level, by removing the heel! And it is already controversial enough to have created significant interest. The heel-less shoe, developed by marathon runner and physiotherapist Adri Hartveld in Staffordshire, UK, the Healus running...
shoe has no midsole or outsole in the rear. According to Hartveld, ‘Healus’ core technology is in the functional design of shoe soles, which reduce the physical stress on body tissues during dynamic movements such as running and jumping. The primary feature in the Healus shoe induces a more plantar-flexed ankle on foot strike, which causes a further increase of shock absorption. The stresses are transferred across the shoe to the ball of the foot for propulsion. Unlike most shoe technologies it facilitates the person’s natural movement strategies for absorbing shock and optimising performance. The Healus shoe has a particular advantage over other running shoes because it is the first and only heel-less running shoe and heel impact is generally known as a common cause of running injury.

Healus technology sets out to provide what Hartveld calls ‘Force Transmission’, which reduces the loading rate of the ground reaction force (shock) when the foot comes into contact with the ground. Strong forces are needed to propel the body during running and jumping activities, but if the loading rate of such forces is too high over long periods of time, the connective tissue in the feet and legs may become inflamed and break down leading to injury. Using the Healus, these stresses are transferred across the shoe to the ball of the foot for propulsion, thus facilitating the wearer’s natural transition in mid-stance for absorbing shocks and optimising running performance. In addition to this the shoe has a hard forward slanting shank-rocker that ensures that the force of the body’s weight decelerates over a greater distance.

A step in the right direction?

In evaluating new concepts in forefoot technology, it is important to understand the intended use of the footwear in question. As the human footstrike position is more varied in running it is easier to compare walking shoe biomechanics where the heel always comes in contact with the ground first. In walking, the foot is in a slightly dorsi-flexed position immediately prior to heel strike. In its most natural state the barefoot lands with a soft convex pad on the lateral border, therefore, by extending the heel of a shoe either at a right angle down towards the ground or in a more exaggerated form, the heel strike occurs earlier than in a normal gait pattern. Conversely, a negative heel will allow the foot to strike later and therefore closer to the natural cadence of the step. One obvious difference is the potential stretching of the Achilles tendon with the lower heel strike action. Another difference is a reduction in cushioning material under the heel, although some would argue that the 15-23mm of fatty tissue under the calcaneous is sufficient padding to achieve adequate shock absorption.

In terms of running footwear, starting with Nike with its low profile Nike Free model, and other established and new brands on the market that are considering the current de-emphasis on heel strike, it is fair to say that biomechanists and shoe designers are taking a fresh look at forefoot technologies in footwear. Stability during gait is of paramount importance but, until recently, the accepted paradigm to improve stability was to construct shoes and inserts to provide proper support for the feet starting at the heel. However, when using shoes that provide stability, the muscles contributing to static and dynamic stability can become weaker because they are not used. Recent studies seem to support the importance of forefoot technologies and an emphasis on strengthening the lower extremity muscles. Is it, therefore, such a leap to consider the foot in a slightly more dorsi-flexed angled position in a negative-heeled shoe? Most of the negative-heeled shoe brands do not recommend using their shoes for competition but suggest rather a ‘training programme’ to readjust the body’s gait pattern.

The medical and scientific juries are studying the empirical evidence from testing results using shoes for improved sports performance with a neutral or decreased angle of plantar-flexion in the sagittal plane. However, in the meantime, for training and walking many thousands of wearers seem to be readjusting their gait patterns in order to wear shoes emphasising forefoot technologies and negative heel concepts.

Marathon runner Adri Hartveld has developed a heel-less shoe that he claims reduces impact forces by around 50%.