Foot Function, Exercise Related Pain and the Influence of Footwear

We live in a world where physical activity is being enthusiastically promoted but exercise related pain and injuries are on the increase. Many people are trapped in a frustrating and 'vicious cycle' of trying to lose weight and improve their metabolic health through regular exercise, only to get injured, become even less active than before and gain even more weight!

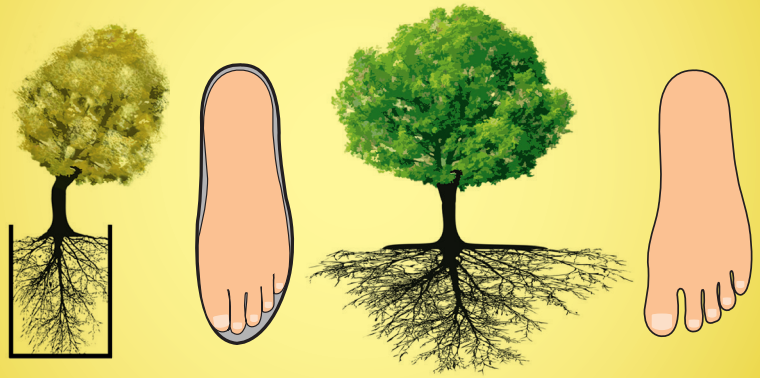
Although Leonardo DaVinci understood that the human foot is a 'masterpiece of engineering and a work of art' the importance of foot structure and function in human movement has been historically neglected or ignored by both the medical professions and the fitness industry.

This brief introduction on the human foot and it's role in exercise related pain and movement dysfunction has been written by a world renowned running coach and a senior university lecturer in Sports Science. Within it's 50 pages a simple biomechanical understanding of the human foot is presented, explaining it's vital role in everyday activities and how footwear is either destructive or restorative to foot function based on our footwear choices.

beNimble

benimble.info

Foot Function, Exercise Related Pain and the Influence of Footwear



Just as the roots of a tree adapt to the shape of the container they are in, the shape of the foot adapts its shape to its "container".

by Lee Saxby & Dr. Mick Wilkinson

All rights are retained, in particular the right of reproduction and distribution as well as the right of translation. No part of the work may in any form - by photocopying, microfilm or another Procedure - without written permission from Joe Nimble® / Lee Saxby reproduced or processed using electronic systems, stored, reproduced or distributed.

© 2018 Joe Nimble® / Lee Saxby

Content

Page

• Exercise: The universal 'Polypill' with side effects 3

• Exercise related pain 6

• Shoe-shaped feet 14

• Shoe-shaped feet, standing posture and back pain 20

• Shoe-shaped feet, walking and knee pain 28

• The epidemiology and etiology of shoe-shaped feet 36

• What type of foot do you have? Take the test 42

• How to fix shoe-shaped feet 48

• How to use functional footwear 53

• References 57

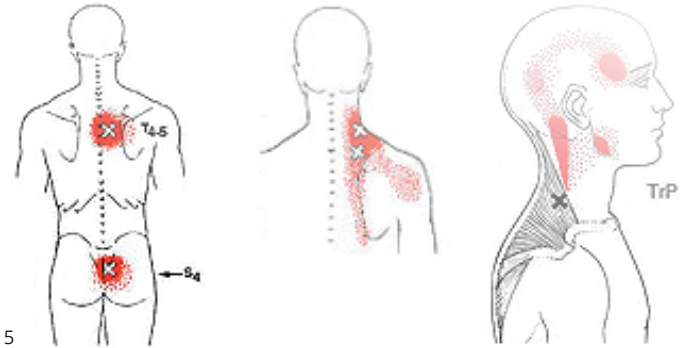
Exercise:
The health ‘Polypill’ with side effects?!

Physical activity and regular exercise have many health benefits, and the public education campaigns to reduce sitting time using standing desks, and to walk 10,000 steps per day are based on established physiological principles and medical research. Unfortunately, it is also clear from medical evidence that risk of lower back pain is more than doubled in populations that continuously stand for over 2hrs per day, and knee pain is cited as the primary reason for sedentary people being unable to exercise or engage in regular physical activity.

For the majority of people frequent ‘sitting breaks’ are the only effective method of relieving both chronic back and knee pain!

'A compromised foot structure is a major perpetuating factor in the development of chronic musculoskeletal pain throughout the body'

Janet Travell, (Pioneer of Trigger Point Therapy)



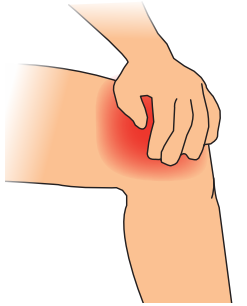
Exercise related pain

70-80% of adults experience back pain during their lifetime

It is estimated that between 70% and 80% of adults experience an episode of low back pain at least once during their lifetime. **The risk of developing back pain doubles in occupations requiring more than 2 hours of standing per work shift**

25-37% of people over 50 suffer chronic knee pain

Knee pain affects an estimated 25–37% of people over 50 and **is the most common reason for giving up sport and exercise in adolescents and adults.** In elderly populations, knee pain is the main reason given for the inability to walk and climb stairs unaided.

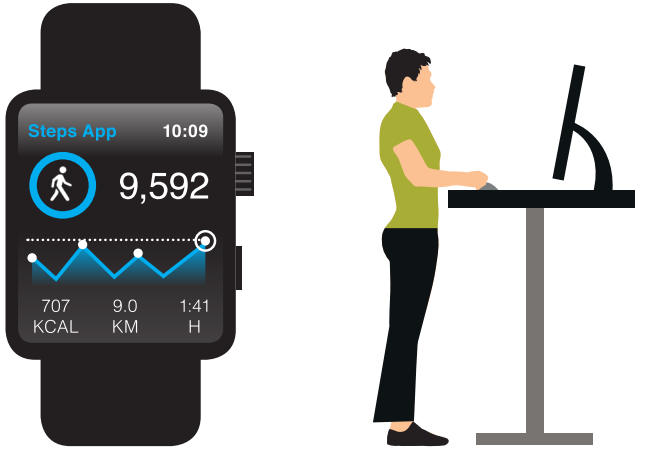


Why?

Foot Function: the missing link in movement-related pain

The most efficient way to increase daily activity and basal metabolic rate is to increase the amount of time spent standing and walking i.e. time on feet. The world-wide recommendation of increasing walking activity to 10,000 steps per day equates to 3,650,000 steps per year and each step loads the supporting leg and foot with forces up to 125% of bodyweight!

Based on these facts, is it any wonder that a dysfunctional foot is often the weak link in exercise and sports biomechanics and a major factor in posture-related pain?



What is the Function of the foot in human movement?

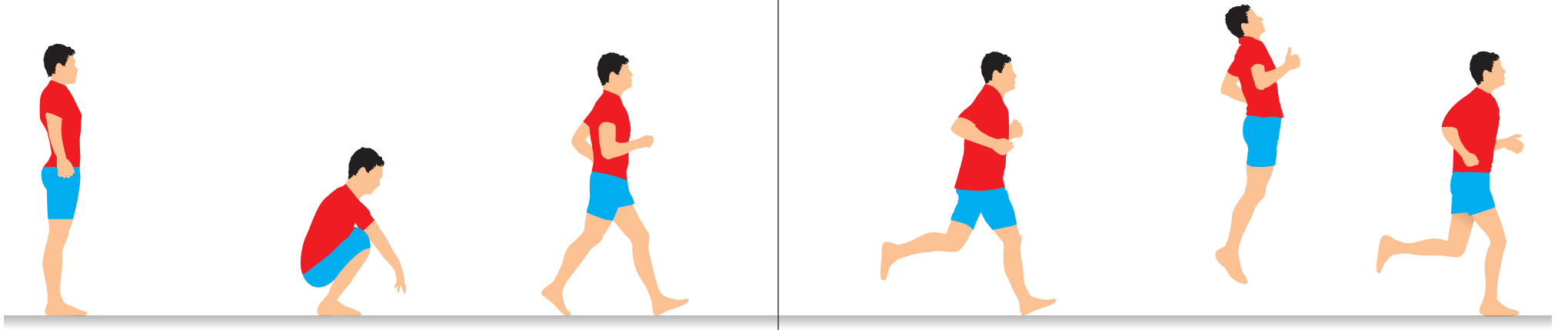
Standing and running are the two movements that represent the natural extremes of foot function: In 'Standing', the foot must be a compliant but stable base of support, providing maximal ground contact and stability in all directions. In 'Running', the foot must become a rigid lever that can store and return elastic energy to aid propulsion in the direction of movement.

The movements of walking and jogging can be considered the intermediate forms of locomotion between standing and running. They require the foot to provide less stability and become more of a lever as speed increases.

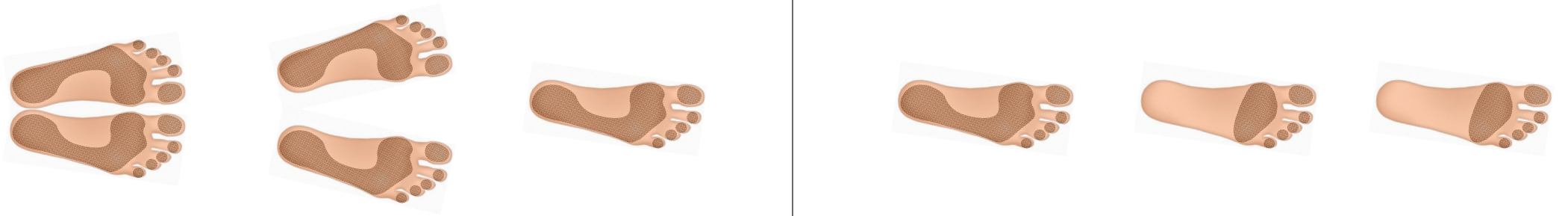
Based on evolutionary theory and the principles of 'biological design', the structure and 'form' of the human foot should reflect the mechanical and energetic requirements placed upon it, and the compromise between its 'static' role (standing and squatting) and its 'dynamic' role (walking, running and jumping)

The static and dynamic function of the human foot

Increased force and instability = increased skill and strength demands on the body **(especially the foot!)**

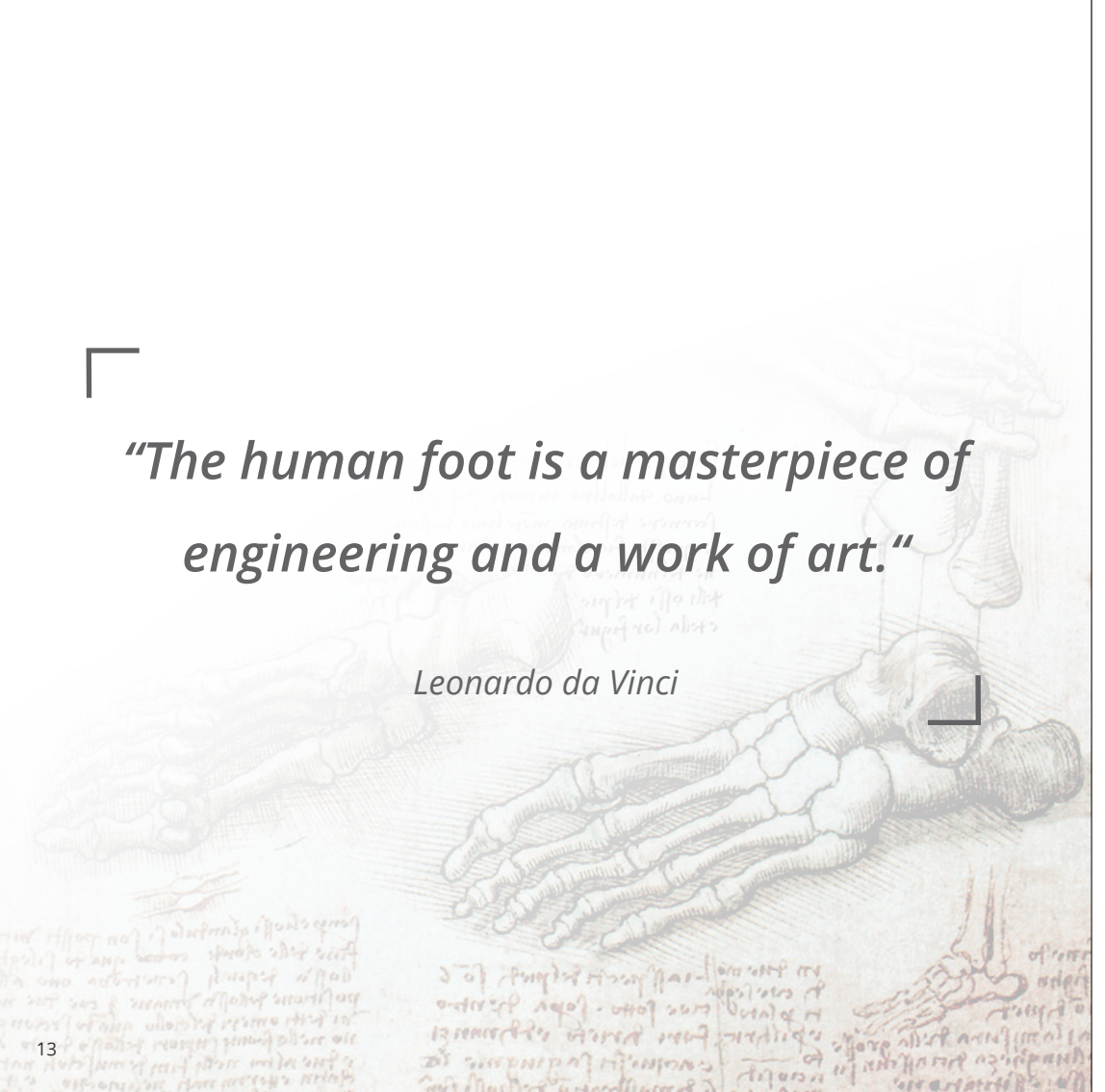


Standing | Squatting | Walking | Jogging | Jumping | Running



“The human foot is a masterpiece of engineering and a work of art.“

Leonardo da Vinci



Shoe-Shaped feet

Proceedings of the Royal Society of Medicine

Section of Physical Medicine

President—James Mennell, M.D.

[*November* 17, 1939]

Foot-gear

PRESIDENT'S ADDRESS

By James Mennell, M.D.

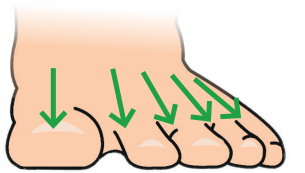
"The human foot is a perfect miracle of mechanical ingenuity and in the vast majority of people it should be perfect throughout life. With the exception of the victims of congenital abnormality or of gross disease or injury, a painless and perfect foot should be our heritage. Of this heritage we have been deprived by our foot-gear and I cannot help feeling that this evil thing is a reflection on the lack of co-operation between the shoe manufacturers, the anatomist and the medical man..."

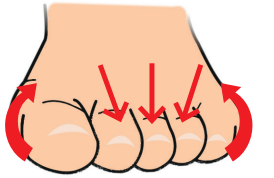
The effects of shoes on the human foot

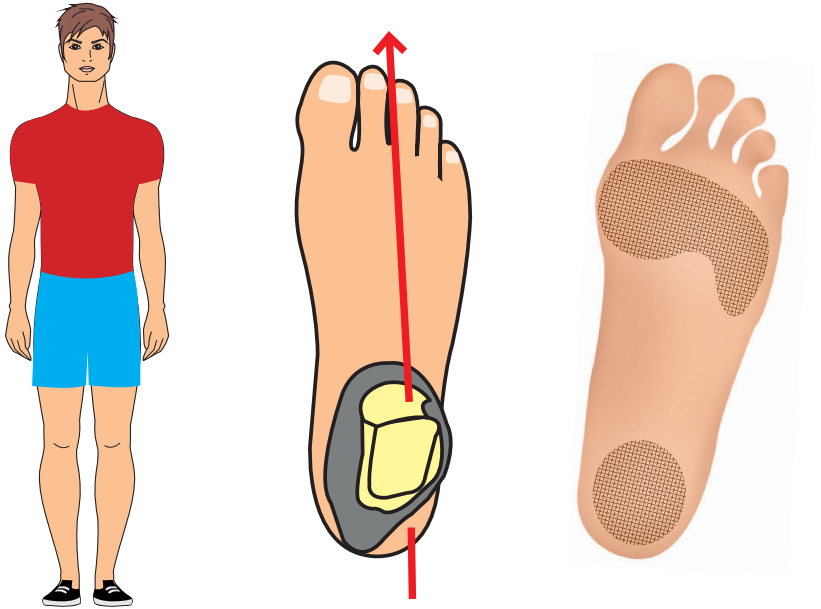
The human foot is remarkably 'plastic' and the habitual use of poorly designed or ill-fitting shoes can have a dramatic effect on its form and function. The 'unshod' human foot (a foot that has never worn shoes) typically has a broad, flat forefoot and toes that are spread out and aligned with the metatarsal heads to give the foot a 'fan-shape'(1). The habitually shod human foot (always in a shoe) has begun to adapt to the footwear being worn and has become 'shoeshaped'. A shoeshaped foot has a narrow forefoot relative to the rear foot, metatarsal heads that are no longer aligned horizontally, and toes that are cramped together, twisted and elevated from the floor.

The Unshod Foot

The Shod Foot



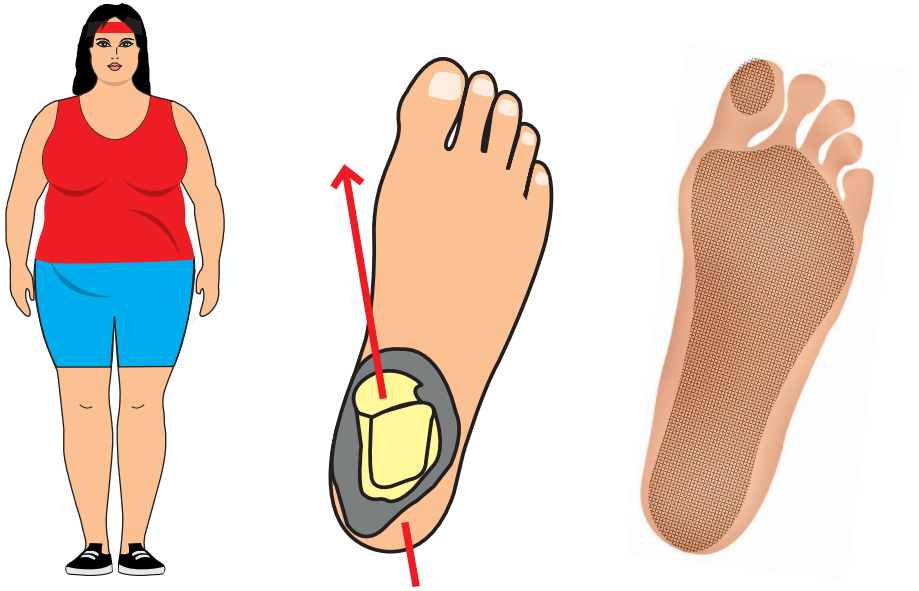




STJ supinated

The rigid shoe-shaped foot and its footprint

In young, athletic people the shoe-shaped foot has high rigid arches
and a supinated subtalar joint



STJ pronated

The collapsed shoe-shaped foot and its footprint

In older, heavier people the shoe-shaped foot has collapsed arches
and a pronated subtalar joint

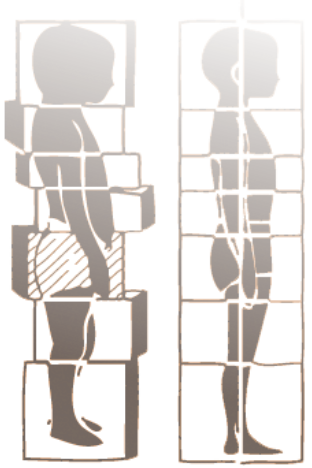
Only by bringing peace

"from the ground up" can problems

higher in the body be "understood"

Ida. P. Rolf

(Founder of 'Structural Integration' and 'Rolfing')



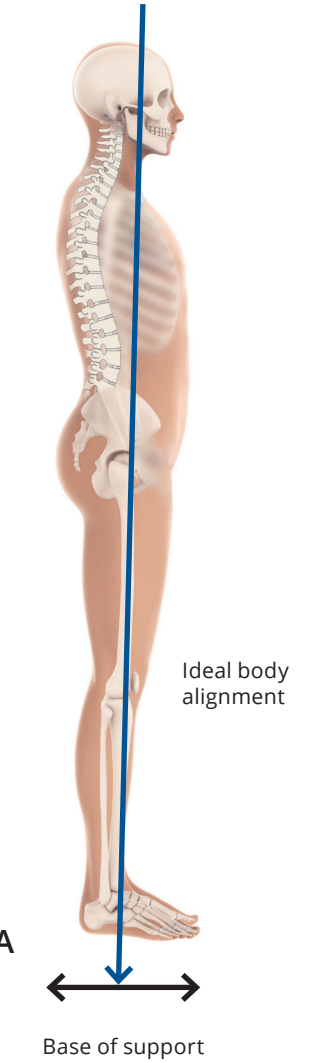
Shoe-shaped feet, standing posture and back pain

What is the ideal standing posture?

Ideal standing posture cannot be defined anatomically due to natural variation in human structure (e.g. relative limb and spine lengths etc.), but it can be defined biomechanically as:

The optimal alignment of the body in relation to gravity and its base of support (feet) which can be maintained with minimal energy expenditure during both static and dynamic loading

Ideal standing posture and functional feet



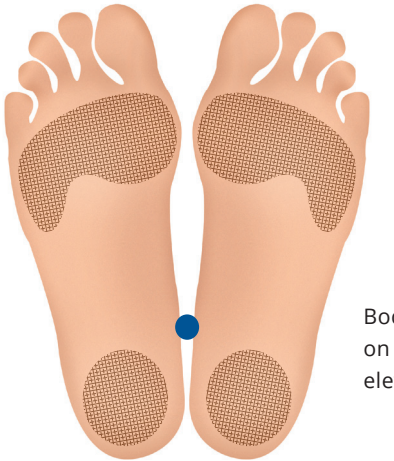
Standing posture and shoe-shaped feet

The typical postural adaptation to a rigid shoe-shaped foot is the ‘sway-back’ standing posture. Due to the poor range of movement available in the ankle joints, the body’s centre of gravity is positioned towards the rear of the foot and the toes are elevated off the ground.

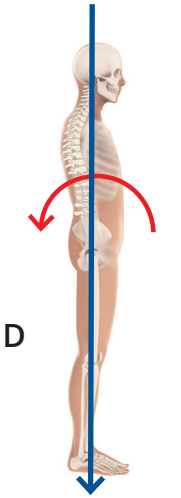
In an attempt to bring the centre of gravity back to the centre of the foot, the pelvis moves forward and is ‘tipped’ backwards on the hips as the torso leans or ‘sways back’ to maintain standing balance.

The most common postural adaptation to a collapsed shoe-shaped foot is the ‘kyphotic-lordotic’ standing posture. The unstable foot structure collapses under load and the pelvis and bodyweight falls forwards and inwards on to the inner part of foot.

These postural misalignments create chronic tension in muscles that must work to maintain balance. They become strained and eventually develop painful trigger points



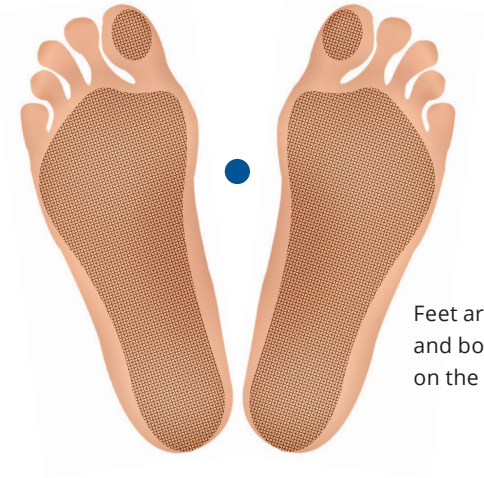
Bodyweight back on heels and toes elevated



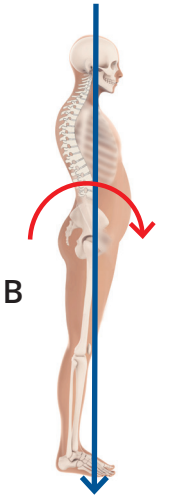
D

Pelvis ‘tips‘ backwards on hips

Sway-back posture



Feet are ‘turned out‘ and bodyweight is on the forefoot



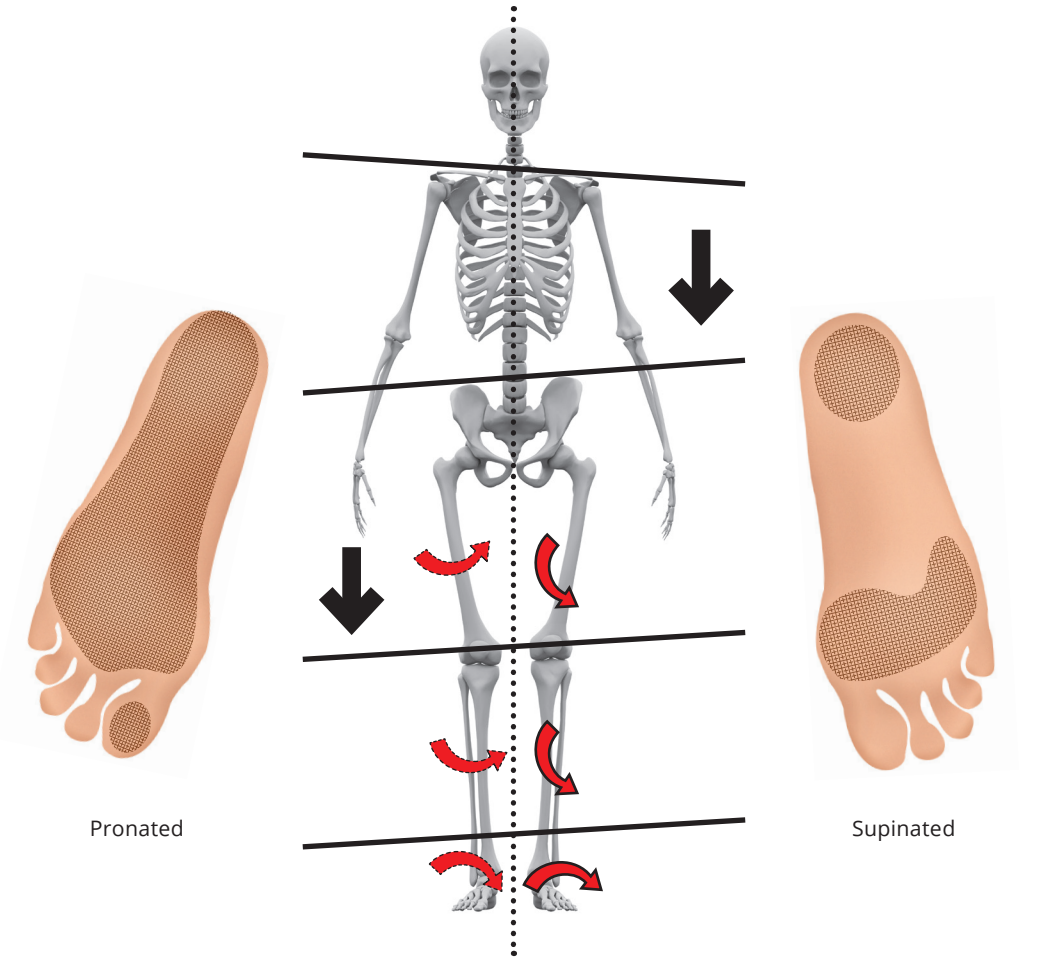
B

Pelvis ‘tips‘ forwards on hips

Kyphotic-lordotic posture.

The asymmetrical standing posture

80% of the population are asymmetrical when weight bearing, with one foot being over pronated (collapsed shoe-shaped foot) and the other foot being supinated (rigid shoe-shaped foot). Normally the 'dominant' side (kicking foot) is over pronated and the 'non-dominant' side is supinated. This 'misaligned' posture is associated with asymmetrical trigger point patterns in the left and right sides of the body (see diagram).



Shoe-shaped feet, walking and knee pain

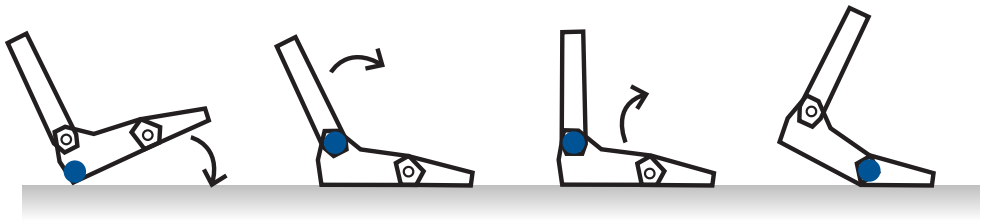
The three functional rockers

The objective of human locomotion (walking and running) is to move the body and its centre of gravity forwards. This requires both STABILITY (so we don't fall over) and MOBILITY so that the body can progress forwards with momentum maintained. The functional human foot and ankle creates a unique pivot system based on a series of three anatomical 'rockers'.

- **THE HEEL ROCKER:** As bodyweight 'falls' onto the lead leg, momentum is preserved by the rounded surface of the heel which acts as a pivot, allowing the foot to roll flat onto the ground.

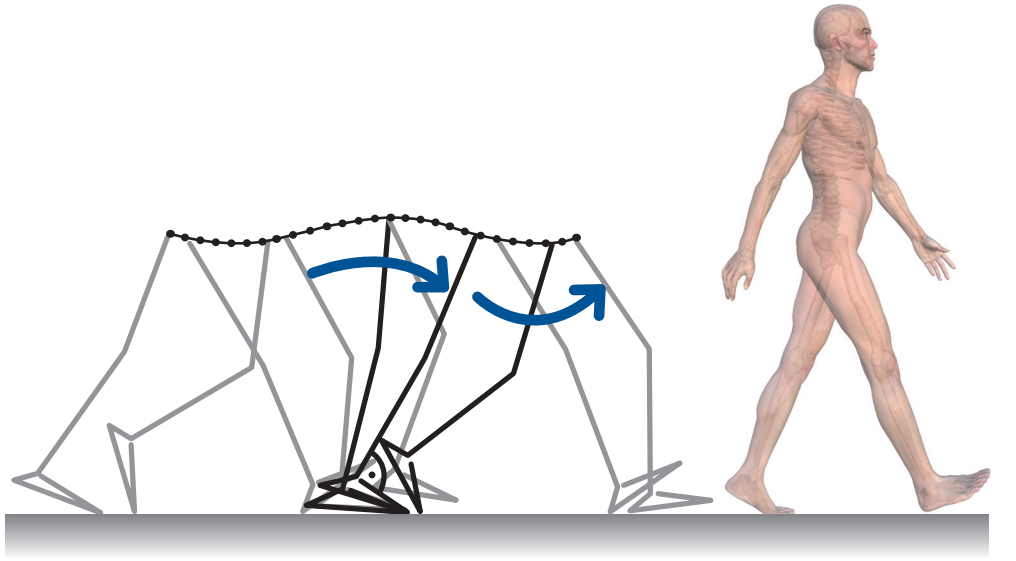
- **THE ANKLE ROCKER:** Once the foot rolls flat to the floor, the ankle joint becomes the next pivot for the continued progression of bodyweight over the length of the foot until it reaches the forefoot (metatarsal heads).

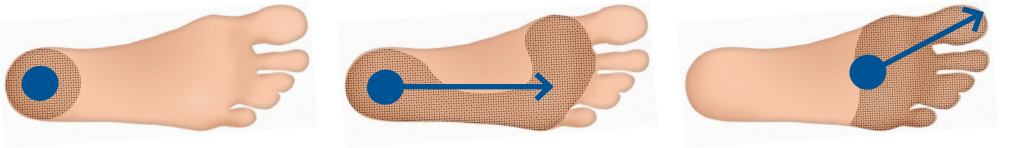
- **THE FOREFOOT ROCKER:** As bodyweight reaches the metatarsal heads, the heel rises and the rounded surface of each metatarsal head serves as a pivot. The toes play a vital role in the forefoot rocker by anchoring the pivot to and increasing its contact area with the ground. Fully functional toes are essential to reduce the pressures experienced by the metatarsal heads and forefoot during walking, running and jumping.



Foot and ankle function in walking
The three anatomical rockers

Walking with a functional foot





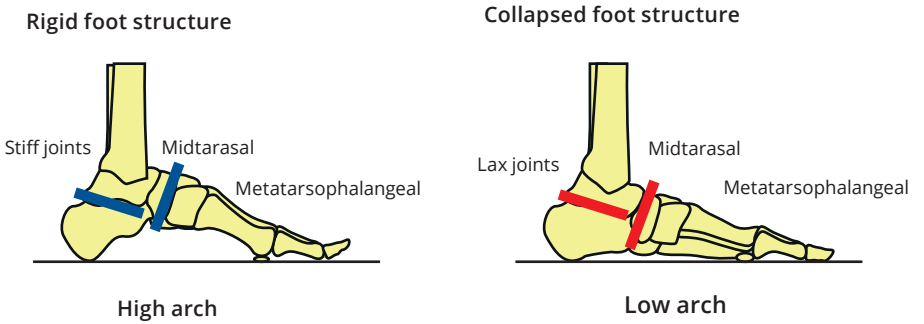
Walking with shoe-shaped feet

THE HEEL ROCKER: In shoe-shaped feet the increased heel pressures during walking can make the heel rocker painful.

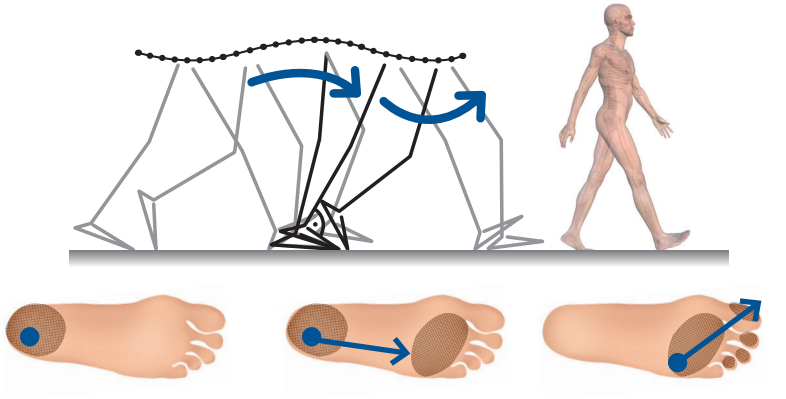
THE ANKLE ROCKER: A shoe-shaped foot normally starts out as a foot with high-rigid arches and a 'supinated' subtalar joint. This foot alignment limits the functional range of the ankle joint and its ability to act as a rocker. To overcome this 'block' in the forward direction (sagittal plane) the body has two strategies:

1. Keep the foot facing in the direction of movement and laterally load the foot and hip to move 'around' the sagittal block. This movement strategy requires a strong compensatory action of the lateral muscles of the lower leg and is associated with the rigid shoe-shaped foot

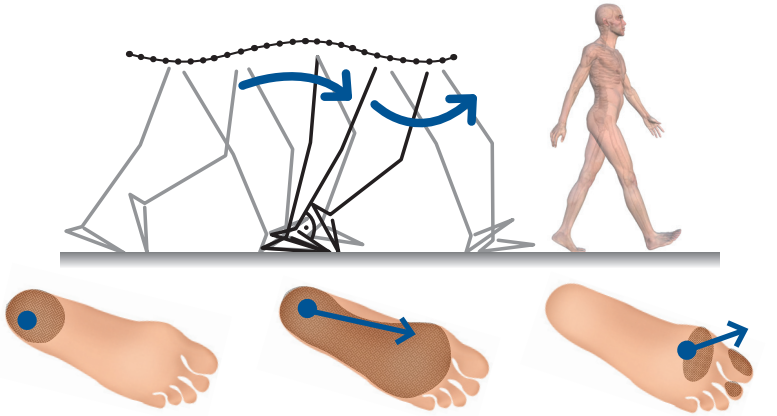
2. Turn the foot 'out' to position the other joints of the foot that normally function in the frontal plane to function in the sagittal (forward) plane to compensate for the blocked ankle joint. These other joints (subtalar and midtarsal) normally function to 'lock' and 'unlock' the foot to become rigid or compliant as required. When repositioned to work in the sagittal plane, the excessive motion and force overload the ligaments that support the joints, creating the collapsed shoe-shaped foot.



Walking with a rigid shoe-shaped foot



Walking with a collapsed shoe-shaped foot

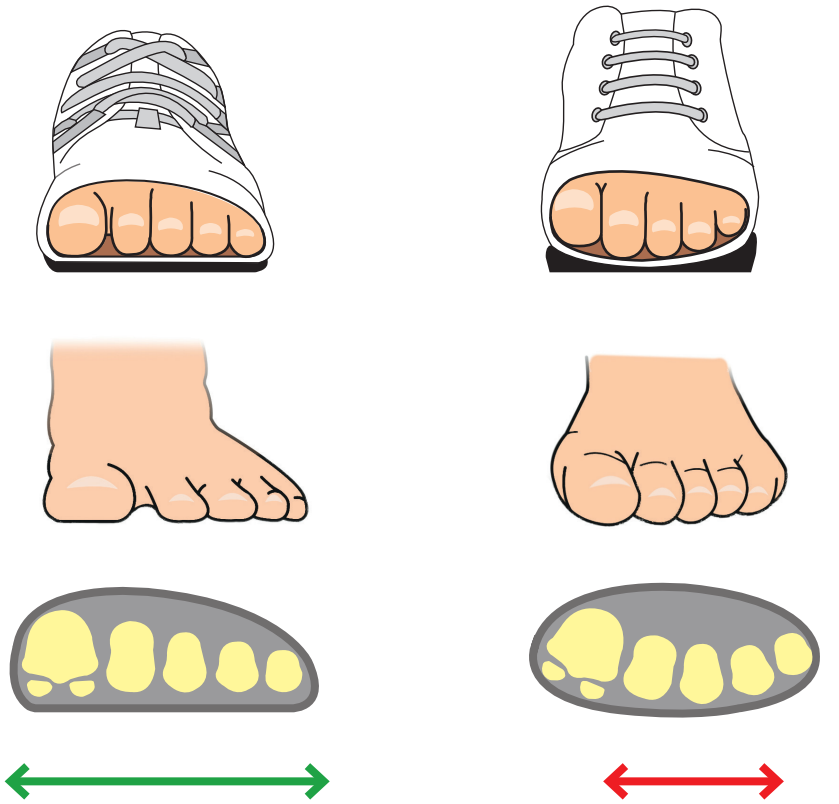


The forefoot rocker:

The main characteristic of ‘shoe-shaped’ feet is compromised forefoot and toe anatomy and function. In both types of shoe-shaped feet, the metatarsals are misaligned in the horizontal plane meaning the forefoot rocker no longer pivots on five metatarsal heads, but usually just three. Pressure on the forefoot due to the reduced contact area of the forefoot rocker is further increased by the inability of the toes to function as ‘stabilisers’, being cramped together and elevated, rather than spread out and flat on the floor.

Increased forefoot pressures and instability created by a compromised ‘forefoot rocker’ and the related toe dysfunction, are the biggest problems associated with ‘shoe-shaped’ feet and are major risk factors for movement-related pain and the biggest problem to overcome for people who wish to transition to more ‘minimal’ footwear.

The shoe-shaped feet forefoot rocker:

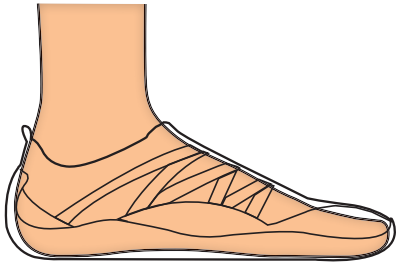


Contact area of forefoot rocker

Reduced contact area of forefoot rocker

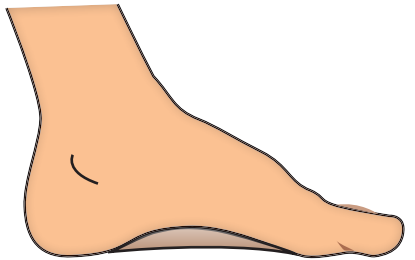
The epidemiology and etiology of shoe-shaped feet

Functional foot (Foot shaped)

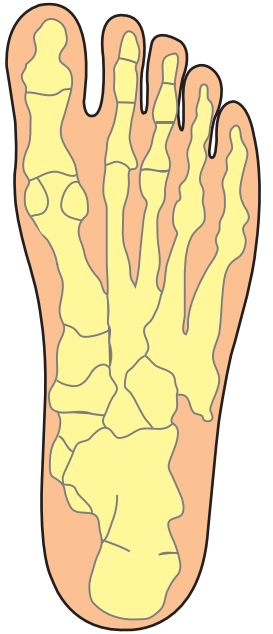


Functional footwear

No toe spring

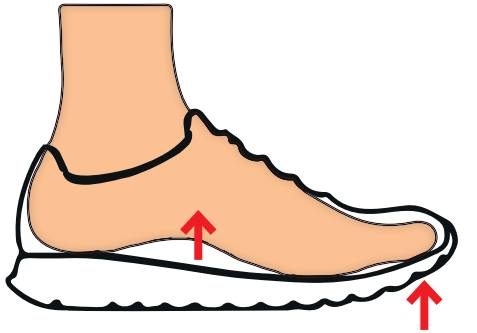


Natural flexible arch



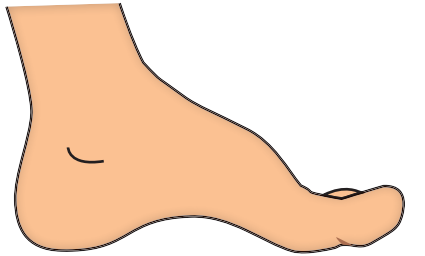
Foot shaped

Dysfunctional foot (Shoe shaped)

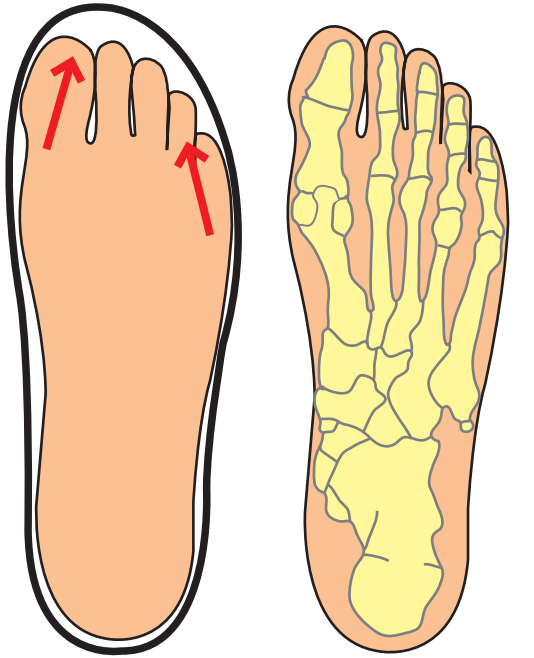


Dysfunctional footwear

Toe spring



High, rigid arch



Shoe shaped

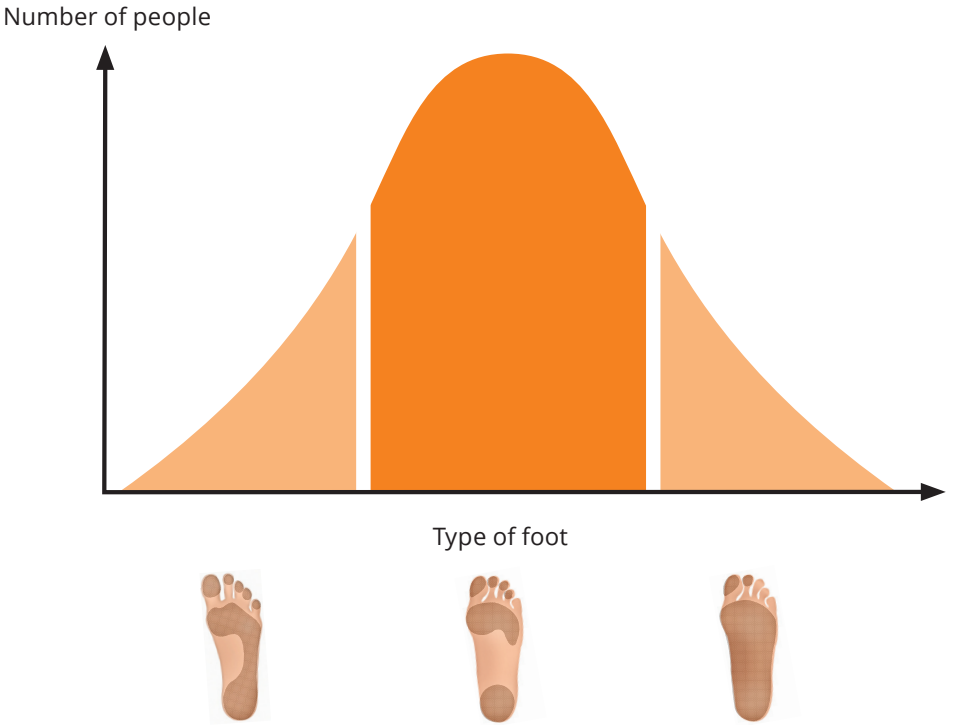
Typical foot shape in industrialised populations

Functional foot

Rigid
shoe-shaped foot

Collapsed
shoe-shaped foot

Distribution of foot types in modern, industralised populations

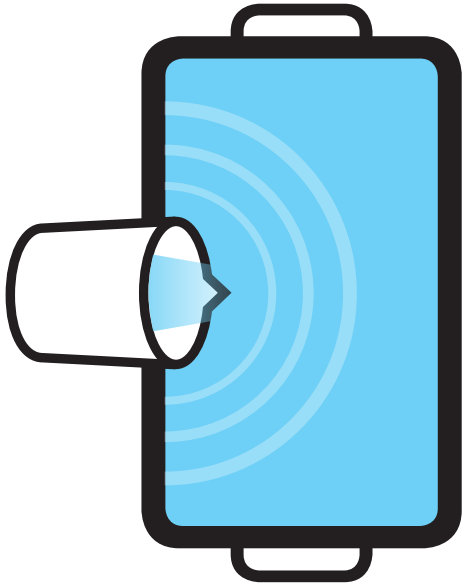


What type of foot do you have?

Take the test

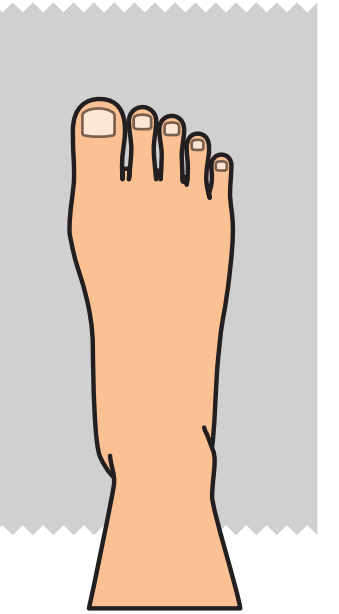
A) At home with the wet footprint test:

1



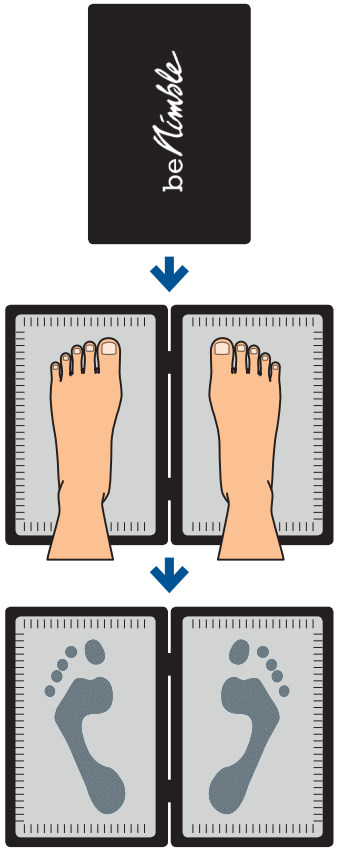
2

3



4

B) With a certified beNimble – Foot Map practitioner



Find a certified beNimble – Foot Map practitioner

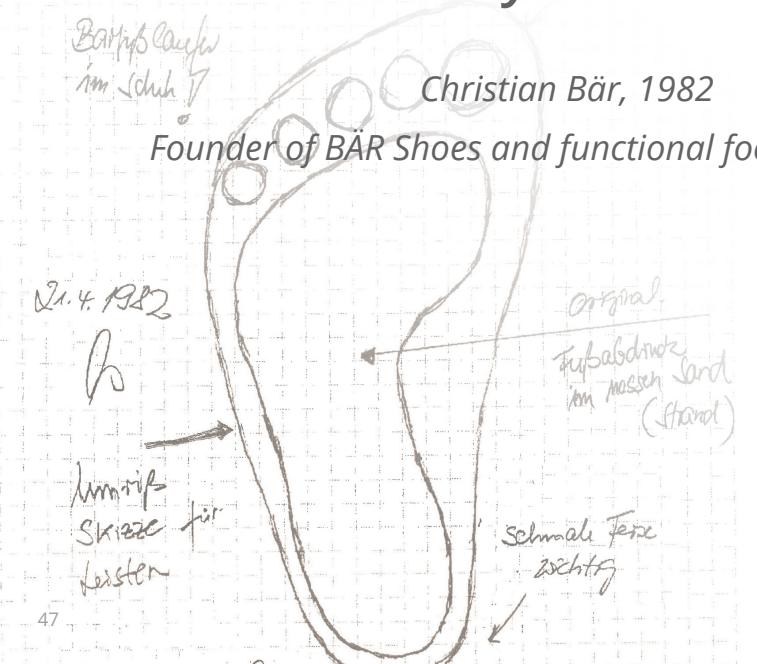
Become a certified beNimble – Foot Map practitioner

Contact us: info@benimble.info

'Shoes should follow the natural shape of the foot and offer uncompromising toe freedom, thereby strengthening the body as a whole'

Christian Bär, 1982

Founder of BÄR Shoes and functional footwear pioneer



How to fix shoe-shaped feet

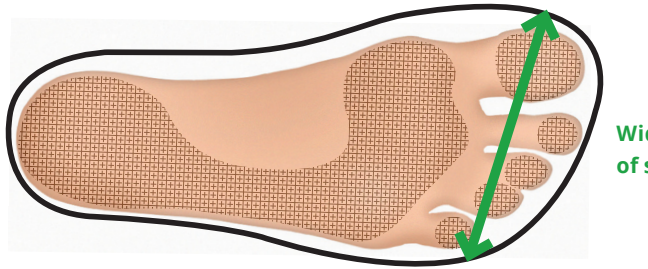
Functional footwear defined

Shoe Design: Restoring foot function begins with restoring its 'form' or shape. **Just as the foot becomes shoe-shaped from wearing shoe-shaped shoes, the foot will become more foots-haped by wearing foot-shaped shoes!** The adaptation of the human body to the mechanical loads and stresses placed upon it is known as 'Wolff's law' in biology, and historically has been used (abused?) by many cultures e.g. chinese foot binding, victorian corsets and the neck coils of the Kayan people.

1- Foot-shaped design: A shoe should mimic the 'fan-shape' of a healthy unshod foot i.e. the widest part of the shoe should be the distance from the base of the great toe to the tip of the smallest toe (the toe-box). 'Wide' shoes that are not foot shaped are just as harmful to foot function as narrow shoe-shaped shoes

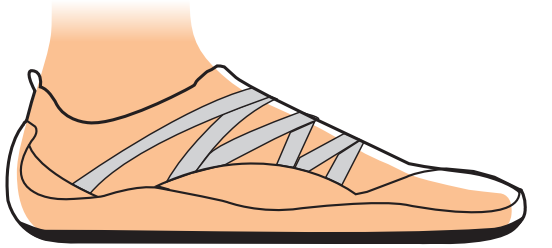
2- Flat sole: The weight–bearing area of the sole should be flat to the floor to provide maximum surface area

3- No toe-spring: The toes can only perform their stabilising role if they are in contact with the ground



1 - Foot-shaped design

2 - Flat sole

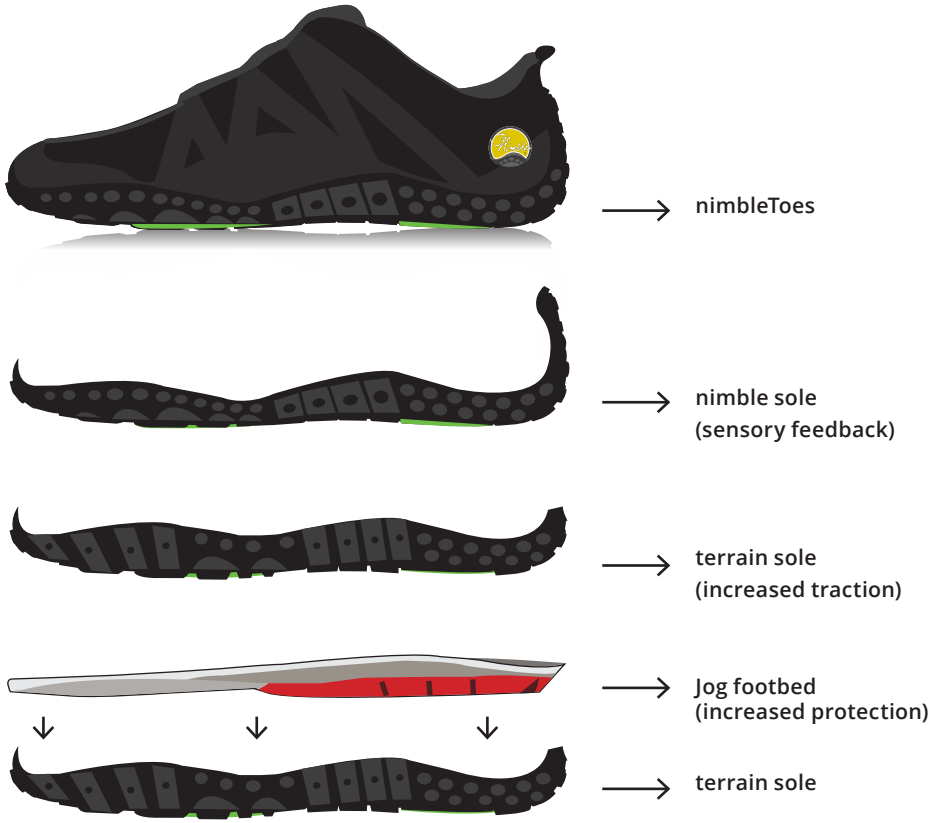


3 - No toe-spring

Sole thickness

The thickness of the sole will vary depending on the activity (forces acting on the foot) and the terrain. **In activities that require maximum sensory feedback, a thin sole is appropriate, but in activities that expose the foot to large, repetitive loads (marathon running) or unstable, irregular substrates (trail running), a thicker sole to provide more cushioning or increased traction is appropriate.**

Functional footwear defined: Sole thickness



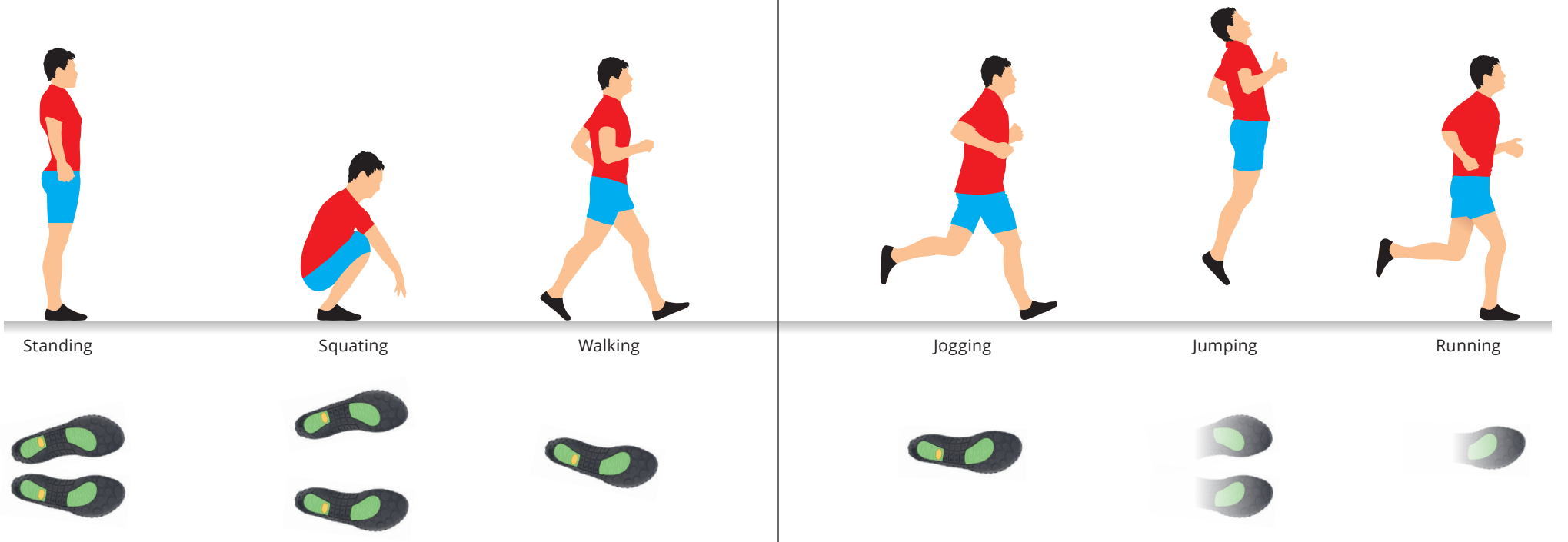
How to use functional footwear

A consistent theme has been repeated throughout this ebook which is the ‘Goldilocks Principle’ i.e. **just as too little exercise is a risk factor to health, too much exercise can also be a risk factor to health, and there is a level of exercise and activity that is ‘just right’ for each individual.** This is the ‘art and science’ of personal training and coaching and beyond the scope of this little book, but there is a template that can be applied based on simple biomechanical theory.

How to use functional footwear

Based on simple physics, the demands on the movement system increase as the forces acting on the body increase (bodyweight) and/or stability decreases e.g. two feet to one foot to just the forefoot. **Start using your functional footwear with the movements on the left and slowly progress towards the movements on the right.**

Increased force and instability = Increased skill and strength demands on the body (especially the foot!)



References

EXERCISE AND ACTIVITY

- Blair SN. Physical inactivity: the biggest public health problem 21st century. British Journal of Sports Medicine (2009)
- Hamilton MT et al. Too Little Exercise and Too Much Sitting: Inactivity Physiology and the need for new recommendations on sedentary Behaviour. Current Cardiovascular Risk Reports, (2008)
- Benden ME. The Evaluation of the Impact of a Stand-Biased Desk on Energy Expenditure and Physical Activity for Elementary School Students. International Journal of Environmental Research and Public Health (2014)
- Wendel ML. Stand-Biased Desks Seated Classrooms and Childhood Obesity: A Randomized Experiment in Texas. American Journal of Public Health Research (2016)
- Exercise and Physical Activity Reference for Health Promotion 2006 (EPAR 2006) Ministry of Health, Labour and Welfare of Japan (2006)
- Wattanapisit. A, Thanamee. S. Evidence behind 10,000 steps walking. Journal of Health Research (2017)
- Tudor-Locke C et al. How Many Steps/day are Enough? For Adults. International Journal of Behavioral Nutrition and Physical Activity (2011)
- Fiuza-Luces C et al Exercise is the Real Polypill. Physiology (2013)
- Hootman JN et al. Epidemiology of musculoskeletal injuries among sedentary and physically active adults. Medicine & Science in Sports and Exercise (2001)

PAIN

- Travell JG & Simons DG. Myofascial Pain and Dysfunction: The Trigger Point Manual (Lower Extremities) Lippincott Williams & Wilkins (1993)
- Travell JG & Simons DG. Myofascial Pain and Dysfunction: The Trigger Point Manual (Upper Half of Body) Lippincott Williams & Wilkins (1993)
- Nelson-Wong E and Callaghan JP. Transient Low Back Pain Development During Standing Predicts Future Clinical Low Back Pain in Previously Asymptomatic Individuals. Spine (2014)
- Gallagher KM et al. The influence of a seated break on prolonged standing induced low back pain development. Ergonomics (2014)
- Nguyen UDT et al. Increasing Prevalence of Knee Pain and Symptomatic Knee Osteoarthritis. Annals of Internal Medicine (2011)
- Gerwin RD. Classification, epidemiology, and natural history of myofascial pain syndrome. Current Pain and Headache Reports (2001)
- Fleckenstein J, Zaps D, Ruger LJ, et al. Discrepancy between prevalence and perceived effectiveness of treatment methods in myofascial pain syndrome: results of a cross-sectional, nationwide survey. BMC Musculoskeletal Disordorders (2010)
- Borg-Stein J, Laccarino M.A. Myofascial Pain Syndrome Treatments. Physical Medicine and Rehabilitation Clinics of North America (2014)

STANDING POSTURE

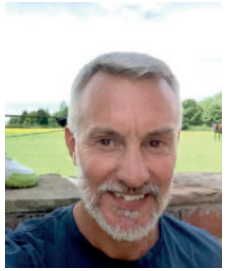
- Kendall, Florence Peterson et al. Muscles Testing and Function with Posture and Pain 4th edition. Williams and Wilkins (1993)
- Sahrmann SA. Diagnosis and Treatment of Movement Impairment Syndromes. Mosby (2002)
- Schamberger W. The Malalignment Syndrome: Implications for Medicine and Sport. Churchill Livingstone (2002)
- Rolf Ida P. ROLFING: Reestablishing the Natural Alignment and Structural Integration of the Human Body for Vitality and Well-Being. Healing Arts Press (1989)

GAIT

- Perry J. Gait Analysis: Normal and Pathological Function. SLACK inc (1992)
- Haskell A, Mann RA. Biomechanics of the Foot and Ankle in DeLee & Drez's Orthoaedic Sports Medicine 3rd Edition. Elsevier (2009)
- Michaud. TC. Human Locomotion: The Conservative Management of Gait-Related Disorders. Newton Biomechanics (2011)
- Barnett CH. The Phases of Human Gait. The Lancet (1956)
- Hughes J et al. The Importance of the Toes in Walking. The Journal of Bone and Joint Surgery (1990)

FOOT FORM AND FUNCTION

- Mennell J. Foot-gear. Proceedings of the Royal Society of Medicine. (1939)
- Hoffman P. Conclusions Drawn From A Comparative Study of Barefooted and Shoe-Wearing Peoples. The American Journal of Orthopedic Surgery (1905)
- Rossi WA. Why Shoes Make “Normal” Gait Impossible: How flaws in footwear affect this complex human function. Podiatry Management (1999)
- D’Aout Ketal . The effects of habitual footwear use: foot shape and function in native barefoot walkers. Footwear Science (2009)
- Janisse DJ. The Art and Science of Fitting Shoes. Foot & Ankle (1992)
- Mei Q et al. A comparative biomechanical analysis of habitually unshod and shod runners based on a foot morphological difference. Human Movement Science (2015)
- McKenzie J. The Foot as a Half-Dome. British Medical Journal (1955)
- Army Foot Measuring and Shoe Fitting System. A manual for commissioned officers. US War Plans Division (1918)
- Harris RI & Beath T. Army foot survey: an investigation of foot ailments in Canadian soldiers. National Research Council of Canada (1947)
- Kirby K. Subtalar Joint Axis Location and Rotational Equilibrium Theory of Foot Function. Journal of the American Podiatric Medical Association (2001)
- Lambrinudi C. The Feet Of The Industrial Worker. Functional Aspect: The Action of the Foot Muscles. The Lancet (1938)
- Lambrinudi C. Use and Abuse of Toes. Post Graduate Medical Journal (1932)
- Mei Q et al. Investigating biomechanical function of toes through external manipulation integrating analysis. Acta of Bioengineering and Biomechanics (2015)
- Rossi WA. Fashion and Foot Deformation: The need for podiatrists to deal with human nature. Podiatry Management (2001)
- Wolff J. Das Gesetz der Transformation der Knochen. Berlin: A Hirschwald, (1892.)



Lee Saxby

Lee Saxby is one of the most recognised coaches for running technique on a global level. Over the last 15 years Lee has been a key figure in the natural movement / barefoot revolution and has been consulted by various shoe companies, university research projects, and injured athletes for his ability to diagnose and correct biomechanical problems. Best-selling author Christopher McDOugall (“Born to run”) as well as the barefoot professor Daniel E. Liebermann (Harvard University) were able to regain their natural athletic abilities through Lee´s coaching methods. Lee works closely together with Joe Nimble developing innovative, holistic movement concepts.

Dr. Mick Wilkinson

Senior Lecturer in Sport and Exercise Science at Northumbria University, Newcastle, UK

Dr Wilkinson’s research area is the biology of human health and performance. His work has included applied sport science with world-class squash players, determinants of performance and training for distance running, and biomechanical aspects of running. Ongoing-funded work is exploring links between plantar sensation and regulation of bipedal gait, the influence of foot structure and footwear on foot function and joint loading in running, and exercise and nutritional impacts on thyroidhormone status, inflammation and markers of metabolic health.