HIDDEN IN PLAIN SIGHT

Summary: **Conclusive evidence based on the new gold standard for joint motion measurement (using dynamic biplanar radiography, CT scans, and 3D computer modeling) indicates that ordinary elevated shoe heels artificially supinate both the subtalar and ankle joints throughout the stance phase of running, including at peak load, and thereby have deformed the entire modern human body.**

Elevated shoe heels plantarflex a wearer's ankle joint. Based on the work of Hicks and a large number of other leading researchers, plantarflexion supinates the **subtalar joint**. Although it therefore follows directly that footwear heels must supinate the subtalar joint, that artificial coupling has been entirely overlooked scientifically. Moreover, the probable effects on human anatomy of that shoe heel-induced supination – external rotation and inversion of the ankle joint – have never been explored.

Taking the first step in correcting that significant omission, an intense investigation was undertaken into the unanticipated effects of this heretofore unexamined artificial biomechanism in human anatomy. This is a brief summary of that investigation.

In an unexpected way, the detailed investigation of the artificial biomechanism summarized here provides so much compelling evidence that it provides grounds for overturning the centuries-old basis of human anatomy. Much of what has heretofore been defined as normal human anatomy and what is abnormal or less highly evolved are in fact completely reversed. In fact, much of what we think of as normal is actually abnormal. The implications of this critical distinction are profound, since modern medical care is based on correctly singling out the abnormal and understanding its cause in order to treat or prevent it.

A probable direct effect of elevated shoe heels on the human foot was published in 1939 in ***The Lancet***: exemplary footprints are the same between individuals who have never worn shoes despite significant genetic differences **(FIGURE 1A).** In comparison, an exemplary modern human foot (in yellow) subjected to the everyday use of modern shoes is externally rotated about **6°** into a **supination** position **(FIGURE 1B)**.

A physical anthropology study from 1931 indicated that a exemplary modern European calcaneus is inverted about **6°** compared to those of two barefoot populations. Note particularly the level lines of the Achilles tendon attachment to the bone on all three samples. That attachment line shows the characteristic supination-based structural tilt to the outside in (**D**) European on the right and not in barefoot Africans (**B & C**) on the left.

This overlooked biomechanism strongly suggests that the elevated heel of modern shoes alone causes an actual physical deviation in the modern foot. My detailed analysis of published data from a 2015 **ISB** prize-winning biomechanical study by **Steffen Willwacher**

et al. in ***Footwear Science*** has produced new and accurate experimental confirmation of that deviation: an average of about **6° of artificial, shoe sole-induced supination** occurs during midstance in running for 222 male and female subjects in modern running shoes.

Furthermore, the **decoupling** of calcaneal/tibial motion observed during running is shown to be directly caused by this artificially-induced supination. It partially counteracts the normal coupling that would otherwise occur naturally. The **6°** supination also interrupts the natural equilibrium between joint forces and creates an abnormal instability that must be compensated for within each runner's body. In general, it forcibly creates idiosyncratic preferred paths of joint motion with unnaturally large ranges of variation.

My result of about **6° of shoe sole-induced supination** during midstance while running is in basic agreement with the typical landing position of the foot while running, which is about **6° of calcaneal inversion** by **Joe Hamill** et al. and about **8° supination** by **Peter Cavanagh,** who with **Ned Frederick** and **Chris Edington** compiled an average **7.2° rearfoot touchdown angle** from thirteen running studies by well-known researchers (compared to an average angle of **1.5°** for modern barefoot runners in three studies).

Moreover, the result is firmly supported by unpublished data from **Dr. Willwacher** that his test subjects had **4° of ankle inversion for males** and **5° of inversion for females** while standing in their own running shoes, which also seems very close to the amount of standing supination shown in the **FIGURE 1B** footprint.

Willwacher's **4° of standing ankle inversion for males** is essentially the same as the **4°** of varus used to put the foot into a neutral position, developed by the noted podiatrist **Steven Subotnick**, who pioneered the treatment of running injuries, at that time mostly of males. In 1976 Dr. Subotnick convinced the **Brooks** Shoe Company to use a **4°** varus wedge in what became for many years its top-rated Brooks Vantage running shoe (and still in widespread industry use today in the equivalent form of midsole density variations).

As illustrated (with exaggerated angle) on the left in **FIGURE 1D**, the varus wedge puts the subtalar joint into a neutral position so that the calcaneus is aligned with the talus and tibia.

Without the varus wedge, as shown on the right in **FIGURE 1D**, the subtalar joint is forced to pronate **4°** unnaturally in order for the calcaneus to align with the level supporting surface below it, and the subtalar joint is thereby left in the inherently unstable position, subject to unnaturally excessive pronation.

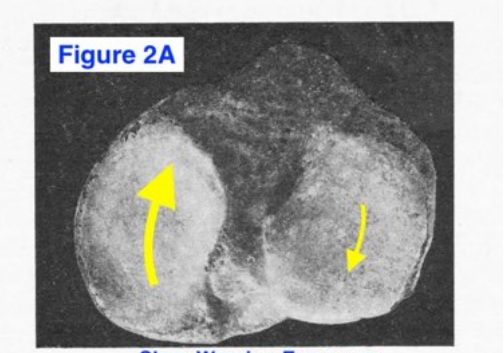
Unfortunately, the varus wedge maintains the heel, ankle, and lower leg in an abnormal varus position, instead of in a naturally stable vertical position. As we will soon see, this causes major structural abnormalities in the human body.

It does indicate clearly, however, that the problem of the anomalous supination position of the modern foot shown on right of **FIGURE 1D** has been well recognized as a fact for many decades. The varus wedge was even recommended for basketball shoes in a classic book, ***Functional Disorders of the Foot***, by Frank Dickson and Rex Diveley, both MD's, in 1939 (ironically, the same year as the unexplained footprints of **FIGURES 1A&B**).

Finally, the same roughly **6°** of calcaneal and rearfoot inversion of the calcaneus and foot is observable using weightbearing cone beam computed tomography in current symptomatic National Basketball Association players. This heel inversion position is so commonly seen at the **Hospital for Special Surgery** in New York that it is officially characterized there as **'... a neutrally aligned hindfoot and slightly increased foot arch'**, as seen in **Figure 1E**.

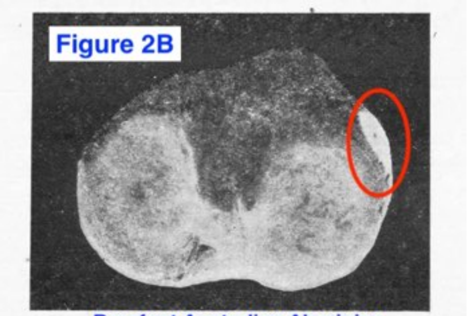
Given the preponderance of all this strong evidence firmly based on peer-reviewed studies and careful clinical evaluation from outstanding researchers, it is difficult to doubt the reality of shoe sole-induced foot supination. What, then, might be its anatomic effects?

Since their motion is coupled, the 6° of shoe heel-induced supination of the modern foot automatically twists the lower leg unnaturally to the outside about 10° during running. That result is similar to Dr. Willwacher's unpublished data that just standing in running shoes creates an average of **5° (male) to 6° (female) of external rotation of the tibia**, which corresponds to about the 4° to 5° of standing foot supination.



Shoe-Wearing European

The shoe heel-induced **10°** outward twisting of the **modern knee joint** creates an unnatural rotary torsion that is directly built into the abnormal bone structure of the modern tibia **(FIGURE 2A)**, enlarging and weakening either or both knees, promoting arthritis and otherwise avoidable patellar, ligament and meniscus damage.



Barefoot Australian Aborigine

In contrast, the rarely injured **natural barefoot knee (FIGURE 2B)** of non-shoe wearers regardless of the diversity of their genetic background has a smaller, simpler structure, with no abnormal rotary motion built into it and with much stronger ligament attachments (iliotibial tract, circled in **red**).

Similar tibia samples from **barefoot Caucasian populations in India (FIGURE 2C)**, show the same simple, non-rotary articular surface structure as the barefoot Australian Aborigine of **(FIGURE 2B)**.

In addition, an **ancient Roman** tibia **(FIGURE 2D)** shows the same simple, non-rotary surface structure as the barefoot Australian and Indians.

The asymmetrically twisted and malformed menisci highlight the abnormality of the modern knee and its cartilage. The medial meniscus is pushed far forward and the lateral meniscus backward **(FIGURE 2E)**, unlike those of a barefoot knee.


Figure 2E
Modern Knee Joint

The outward tilted tibia causes the knee ligaments to loosen on one side of the joint, allowing motion, and tighten on the other side, creating a relatively fixed center of rotation.

It is already well-established in evolutionary terms that the human body was born to run. In terms of the evolution-in-reverse in operation today, the artificial conversion of the modern human body from natural to abnormal, with a twisted and deformed bone structure built by aberrant rotary torsion, occurs during running with elevated shoe heels. Astonishingly, the effect of the small **6°** supination deviation cascades throughout the entire modern human body, slowly deforming and destabilizing every part of it.

That is because the **6°** deviation occurs during running, when the highest repetitive forces in the human body are experienced. That pounding, highly repetitive load of 2-3 times bodyweight controls bone growth and joint formation during the critical childhood and adolescence growth phases, a time when running occurs frequently – all as dictated by Wolff's Law on bone growth.

An **African Bushman (FIGURE 3A)** who grew up barefoot has a typical **natural body structure**: symmetrical with straight legs and level pelvis when running, with no leg crossover and well-defined spine, as well as minimal supination or pronation. Other photographic evidence indicates that **Asians** and **Caucasians** who have not worn conventional modern shoes**,** such as Kim Phuc as a child and Zola Budd as a young adult, have the same typical natural body structure.

In contrast, the typical modern body of a **shod Finnish marathoner (FIGURE 3B)**, who doubtless grew up wearing modern shoes, is **unnaturally deformed: his legs and torso are both tilted and twisted away from a vertical centerline**.

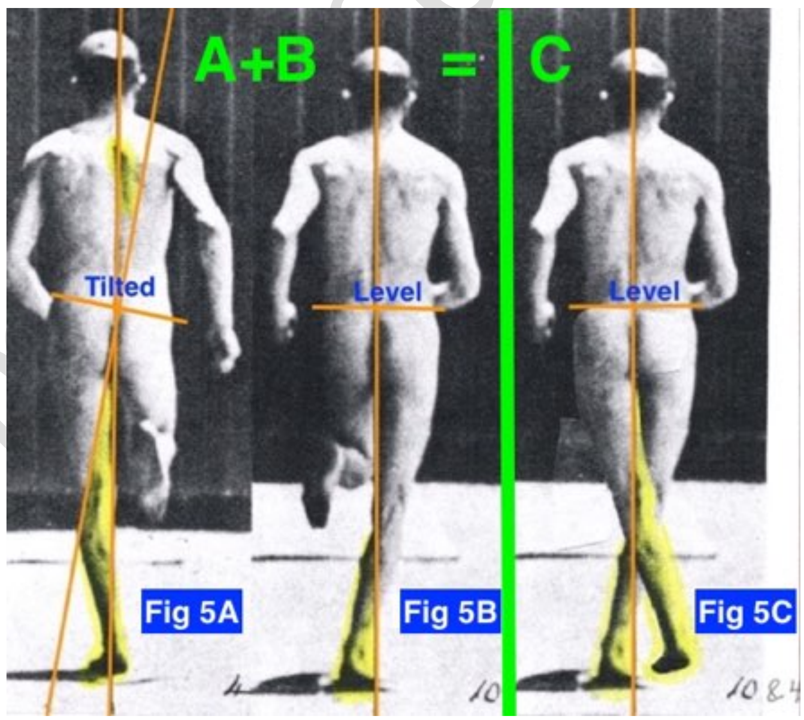
His support leg is bent-out into a bow-legged position by his shoe heel-induced supinated feet, and he has a twisted pelvis and bent-out spine with shallow definition, with unnatural thoracic torsion abnormally distorting the chest and subjecting the heart to unusual repetitive pressure, thereby promoting heart disease.

The neck and head of the **Finn** are tilted-**in** to counterbalance his tilted-**out** spine, so it is even possible to speculate that, just like the modern knee, the twisted modern human brain itself is an artificial structural reaction to unnatural rotary torsion caused by shoe heels.

Even the most elite modern athletes, like **Roger Bannister** breaking the 4-minute mile barrier **(FIGURE 4)**, demonstrate the same misaligned and deformed body structure under the duress of maximum effort, in contrast to upright and aligned structure of the barefoot **Bushman** of **FIGURE 3A**.

During running, at the point of maximum load of 2-3 times body weight, the effect of modern shoe-supinated feet is to automatically tilt both left and right legs unnaturally inward, crossing over the centerline of the body. **(FIGURES 5 A+B)**

Consequently, **a modern runner's pelvis is forced to tilt down abnormally (FIGURE 5A)** on at least one side to prevent the feet and legs from crossing over the body's centerline and thereby colliding directly into each other. Otherwise, if a modern runner's **pelvis is artificially kept leveled (FIGURE 5C), instead of tilted**, his maximally flexed and loaded legs become so criss-crossed that running would be impossible.



That theoretical level pelvis position **(FIGURE 5C)** shows the true relative position of the hip joints between both the pelvis and the legs at peak load when running, the position in which those lower extremity joints are all unnaturally deformed by that peak load.

The absurdly unnatural crossed-leg position deforms the bone structure of the hip joints, bending it into an abnormally adducted position, which weakens the hip and restricts its natural range of motion, promoting fractures. The neck of the femur is also unnaturally deformed and weakened, bending into an abnormal position in both the frontal and transverse planes. The pelvis itself is deformed because of the unnatural outward horizontal force component at the hip joint created by the abnormal bent-in position of the legs, making the pelvis wider and flatter, thereby reducing the birth canal width.

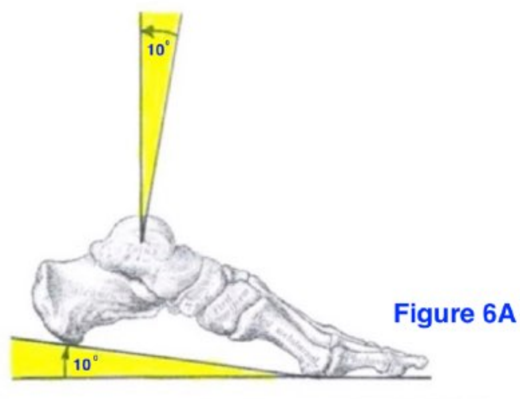
Again, supporting evidence comes from published and unpublished data from Dr. Willwacher's earlier cited study. The standing hip angle for 222 test male and **female** test subjects is **2°** to 3° of abduction or tilting-out of the leg, not adduction (tilting-in).

However, at the very beginning of the stance phase of running, the initial hip angle immediately becomes 8° to **10°** of adduction (tilting-in), not abduction. This is an **amazing** change, the total the hip angle increasing by a full 11° to **12°** of **in**ward tilt, a dramatically abrupt difference in the transition from standing to running on the support leg.

Even more extraordinary is the fact that at peak load midstance, the hip adduction angle for females climbs to **17°** and to **14°** for males. The total hip angle adduction or tilting-in change from standing to peak load running is **19°** for females and **17°** for males. For the typical barefoot runner shown in **FIGURE 3A**, the support leg is almost vertical!

An obvious question arises. What causes both legs to be bent-**in** so far from their natural vertical position? The answer, which at first sounds more confusing than helpful, is that both legs actually are being bent-**out** unnaturally by both ankle joints.

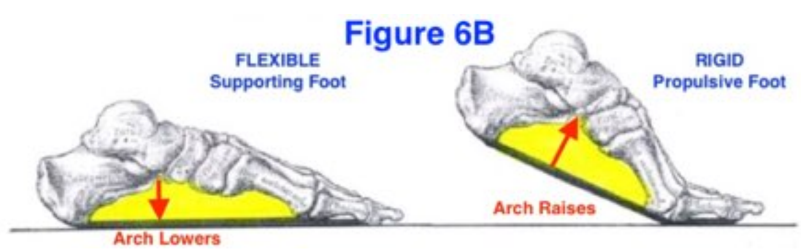
The observed bent-**in** position of both legs is because both legs are anchored to the body at the hip joint, but obviously not anchored at the ground, so the counterintuitive answer is: the legs – that are abnormally bent-**out** by the moveable ankles – are in direct reaction forcibly bent-**in** by the relatively unmovable hip joints (fixed by torso inertia).



That answer, of course, only leads to another obvious question, which is the most fundamental of all. What causes both ankle joints to unnaturally bend-out each leg?

The more helpful answer is a scientific discovery that explains all the previous anomalies of the modern human body: the modern foot is forced into an abnormally supinated position by a hidden effect of the relatively modern **elevated shoe heel**.

It is obvious, of course, if the shoe heel moves the foot heel up by, say 10°, the front of the foot is tilted down by 10° into what is called a plantarflexed position **(FIGURE 6A)**.



The hidden effect of the abnormal plantarflexed position is that it activates a well-known **windlass mechanism** of the foot, which normally converts the flexible supporting position of the foot on the ground into a rigid lever to propel the body forward in locomotion **(FIGURE 6B)**. The windlass mechanism automatically externally rotates the position of the ankle bone (talus) on top of the calcaneus (heel), so that the subtalar joint points to the outside.

The elevated shoe heel artificially forces the foot into the unnatural **supinated position** **(FIGURE 6C)** when it naturally should be flexibly supportive on the ground. That is an unfortunate and critical change. The automatic shoe heel-induced mechanism unnaturally points both the ankle joint and the lower leg to the outside, instead of straight ahead.

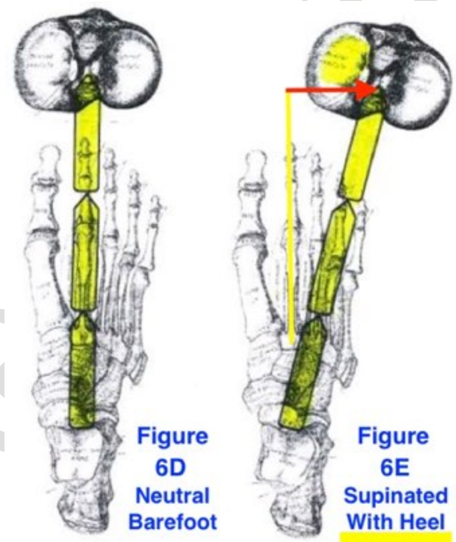
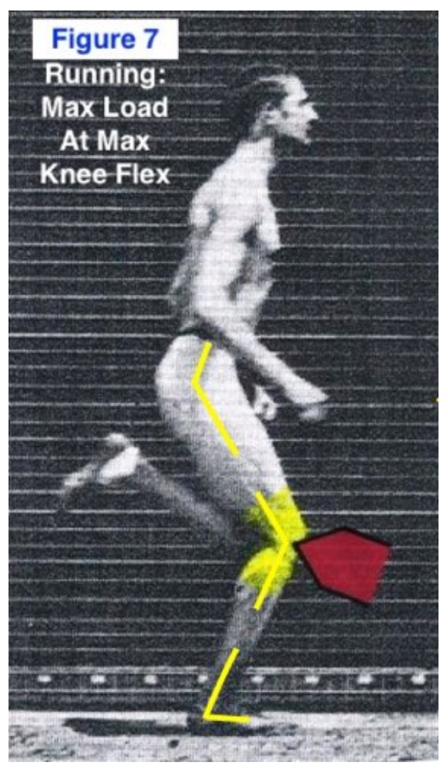


FIGURE 6D shows a natural, unshod right foot and the natural, un-twisted right knee position pointed straight ahead in the flexed-knee midstance running position. The ankle joint is pointed straight ahead and the knee joint is flexed to absorb the full force of body weight, especially when running at the maximally loaded midstance position of **FIGURE 7**.

FIGURE 6E, in contrast, shows the unnatural, maximally loaded, tilted out right knee position caused by an elevated shoe heel when walking and especially running, at the maximally loaded midstance position of **FIGURE 7**.

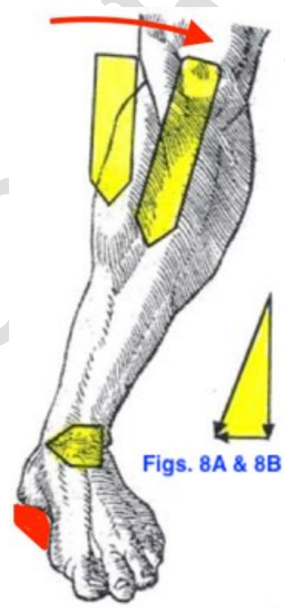


The outwardly rotated ankle joint forces the knee to twist to the outside. **FIGURE 6E** also shows that the inside (medial) half of the knee joint abnormally carries most of that maximal load, an amount as great as 80-90% for some individuals, due to the tilting-out of the knee to the side.

That hidden effect is relatively inconsequential when standing or walking, but, when running, the hidden effect is severely deformative. The reason the hidden shoe heel effect is so consequential when running is that the peak load of two-to-three times body weight occurs at exactly the worst possible time: when knee, hip, and ankle joints are maximally flexed. **(FIGURE 7)**

Runners' Legs Are Forced into an Inherently Unstable, Twisted & Tilted-Out Position by Elevated Shoe Heels

FIGURE 8A below shows a front prospective view of the tilted-out runner's leg shown previously in **FIGURE 6B**. Whereas the leg would be naturally stable if vertical, it is unavoidably unstable in the twisted and tilted-out position forced by an **elevated shoe heel**.



Figs. 8A & 8B

In terms of simple classical physics, this angled force vector of body weight carried by the runner's leg resolves into a vertical component vector and a horizontal component vector, as shown in **FIGURE 8B**. The horizontal component is critical, since it unnaturally forces the subtalar joint inward, thereby causing the foot to pronate inward unnaturally. If the runner's leg remained naturally vertical, there would be only a vertical force vector, with no horizontal component vector.

Remarkably, evidence indicates that **never-shod barefoot runners do not pronate** with each running stride because they have untilted, vertical legs, like the Bushman in **FIGURE 3A**, as well as the Bantus of South Africa. Only runners exposed to longtime use of elevated shoe heels are forced to pronate unnaturally with every running stride!

A natural, vertical leg is inherently in equilibrium. The downward body weight force is balanced by a matching upward ground reaction force. In contrast, the unnatural shoe heel sets up a fundamental structural instability, as shown above in **FIGURES 8A&B**.

The lower leg shown in **Figures 8A & 8B** has an about 8° varus position that is almost constant throughout the stance phase of running. It creates an artificial horizontal force vector component of the ground reaction force (GRF) in the medial direction that powers compensating rearfoot eversion that would not be present in a vertical leg. This medial horizontal force component has been measured recently with a magnitude of slightly more than 2% of the GRF for 25 runners (Zifchock, Parker, Wan, Neary, Song, and Hillstrom, 2019).

The same study includes extraordinary evidence of a lateral horizontal force component with a magnitude of almost 4% of GRF, which is almost twice the magnitude of the medial force component.

There is no explanation for the source of such a lateral horizontal force component except as a direct effect of shoe heel-induced subtalar supination. It appears therefore to provide empirical confirmation of that artificial coupling.

THE UNNATURAL CAUSE: SUPINATION In summary, as shown in **FIGURES 6B & 8A**, the elevated shoe heel unnaturally forces the knee to tilt outward in the frontal plane into an abnormal bow-legged position. As a result, the ankle joint is unnaturally de-stabilized. The full body weight load acting on the ankle joint is tilted into an unnatural angle, rather than remaining vertical, which would be naturally stable. This is the action.

THE UNNATURAL EFFECT: PRONATION Simultaneously, in compensation to the abnormal bow-legged position, the ankle is unnaturally forced inward by an unstable horizontal force vector resulting from the tilted lower leg, resulting in unnatural pronation, as shown in **FIGURES 8A&B**. This is the reaction.

Simply put, the unnaturally supinated foot directly forces the foot to pronate unnaturally in reaction.

POWERFUL EVIDENCE OF SUBSTANTIAL SUBTALAR AND ANKLE JOINT SUPINATION THROUGHOUT RUNNING STANCE FROM A NEW GOLD STANDARD IN JOINT MOTION MEASUREMENT ACCURACY

Now, for the first time, truly accurate measurements of the subtalar and ankle joints during running have been made in a study **(Peltz et al., 2014**) that used new gold standard 3D radiographic and computer modeling techniques. The new measurements make all previous measurements using older, less precise techniques obsolete due to their relative inaccuracy.

The new results are startlingly unexpected, the opposite of the previous understanding, which was that pronation of the subtalar joint and eversion of the ankle joint predominated at peak load during running midstance. Instead, **both subtalar and ankle joints were found to be substantially supinated during midstance running, with an extraordinary combined total of about 8° of inversion and 20° of external rotation at peak load.** The subtalar joint provides about 5-6° of the inversion and the ankle joint provides about 12° of the external rotation.

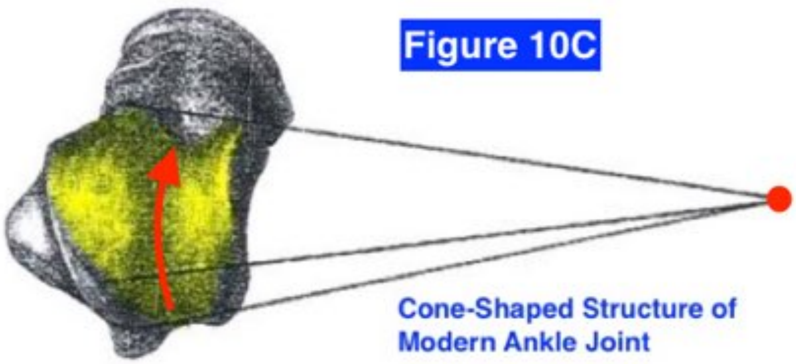
Like the modern rotary knee joint, the modern (left) ankle bone shown in **FIGURE 10B & 10C** shows the same rotary motion induced enlargement, as well as a lateral side angled enlargement, when compared to a natural ancient barefoot Egyptian (left) ankle bone or Anglo-Saxon (right) ankle bone shown in **FIGURE 10A & 10C1.**

The barefoot ankle operates like a section of a pulley or wheel to efficiently perform its basic simple hinge function.

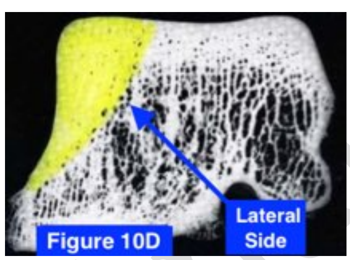
FIGURE 10C shows more definitively the well-known but unnatural rotary structure built into the **modern elevated shoe heel wearing Englishman**'s (left) ankle joint (ankle joint trochlear surfaces highlighted in yellow).

Again, like the modern rotary knee joint, the outward tilted tibia causes the modern (left) ankle's ligaments to loosen on one side of the joint, allowing motion, and tighten on the other side, creating a relatively fixed center of rotation. However, in this case, based on the governing simple geometry, **the joint sides <u>reverse</u> their roles, with the lateral side on the modern ankle joint becoming looser and the medial side becoming more fixed, as shown in a frontal plane schematically in FIGURE 9G, resulting in the rotary joint structure shown in FIGURE 10C.**

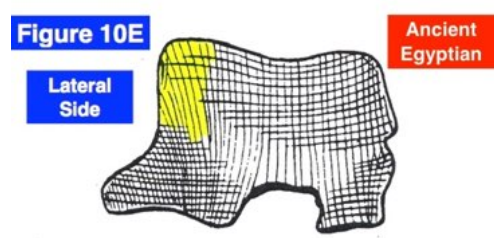
In marked contrast, the right ankle joint of an **ancient barefoot Anglo-Saxon** of **FIGURE 10C1** shows no rotary structure compared to that of a modern Englishman in **FIGURE 10C**, and has a medial side that is just as long as the lateral side.



As a result, the anterior **lateral** side of the **modern talus**' trochlear joint surface develops a <u>much more dense</u> network of underlying trabeculae, shown highlighted in yellow in **FIGURE 10D**, in a coronal plane cross-section of the anterior joint surface that is load-bearing under peak load during running, as shown in **FIGURE 7**.



In contrast, **the ancient Egyptian talus shows the <u>opposite</u>** structure – a <u>much less dense</u> trabecular network on the lateral side, as shown highlighted in **FIGURE 10E**. In fact, the much greater density in the trabecular network of the **medial** side indicates that the medial side is the dominant load-bearing side of the natural Egyptian talus.



Showing the arrangement of the lamellæ in a trans-section through the corpus.

The modern feature of the wedge-shaped ankle joint is well-known in shod modern populations, including the well-defined artificial extension of the anterior lateral portion of the trochlear surface was observed in 152 specimens, as indicated in a Figure 7 of Plate 1 of a Barnett & Napier study.

In contrast, parallel-sided modern shod tali as shown in Barnett's Figure 8 of Plate 1 are rare in modern shod populations. Perhaps even more interesting is that the rare parallel-sided tali have a fixed horizontal axis of rotation characteristic of barefoot tali, as shown in his Figures 3 and 4 of Plate 1.

Where the action and reaction forces balance in equilibrium for each leg of any given individual is dependent on that individual's personal body structure and chance in the form of personal injury.

The simultaneous dual interaction of action and reaction is **strictly biomechanical**. It is an automatic and unavoidable action and reaction, both unnatural and artificially caused by elevated shoe heels.

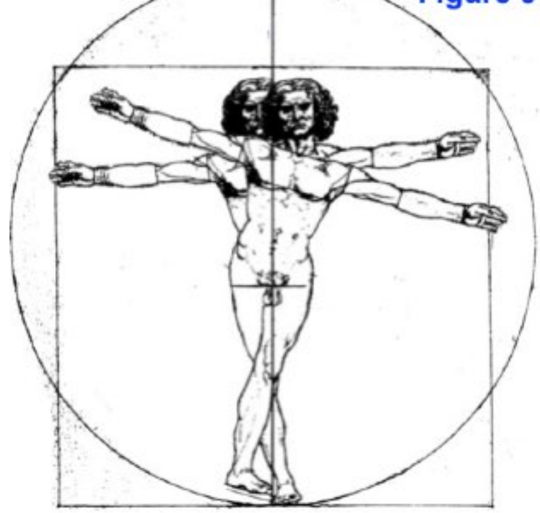
Therefore, the repetitive peak joint loading occurs just when the maximal abnormal knee, hip and ankle joint bending occurs – while unnaturally rotated to the outside by elevated shoe heels. That directly results in a closed chain of structural misalignments throughout the modern human body, artificially deforming all of it from natural to abnormal.

The unnatural deforming occurs as prescribed by **Wolff's Law**, which requires that bone is remodeled by the maximum loads to which it is subjected. Similarly, the soft tissues of all of the joints – the ligaments, cartilage, tendons, and fascia – also are remodeled by the maximum stresses to which they are subjected by **Davis's Law**.

FIGURE 9 provides an overview of the structure of the **unnaturally deformed modern human body**, as specifically degraded by running with elevated shoe heels.

Its primary deformities, like those of the Finnish runner, consist of abnormally bent-in legs forcibly tilting and twisting the pelvis, resulting in an unnaturally bent-out lumbar and thoracic spine, as well as tilted-in cervical spine and head. As a result, the entire modern body is structurally destabilized and functionally impaired.

Figure 9



Once those asymmetrical deformities are initially developed in childhood and adolescence during running with elevated shoe heels, they become locked into the bone and joint structure of adults, as shown in the knee example **(FIGURE 2A)**. These deformities become worse over time with continued running as adults, of course, but also become worse for older adults who only walk, even though walking did not create the original deformities.

Once formed, the deformities continue to increase inexorably throughout adult life. They become fully evident in the unnaturally stooped posture of the elderly, for whom walking or standing is often difficult or impossible.

Given the link between shoe heels and the anatomical damage they inflict biomechanically on virtually every part of the modern human body, the associated medical costs for shoe heels in the United States alone could well be as high as $1.5 trillion each year. Although these financial costs are shocking, the effect of elevated shoe heels on our general well-being is even more costly. In the course of our lifetime – but especially as we age – shoe heels drastically degrade our overall health and quality of life.

There really is no way to describe the untenable situation that we, as modern shoe-wearers, are all trapped in now, except to say that all of us have been little more than **Guinea Pigs** throughout our lives and remain so today.

At least for now, we are all inadvertently trapped, involuntarily enrolled in a huge, unguided experiment in reverse-evolution that first began for each of us as a fetus in our mother's modern womb (unnaturally formed and functioning), then continued when we took our first infant steps in baby shoes, and continues uninterrupted today.

Each day our bodies become more deformed and farther away from their true natural state. For now, we know little about how to stop or even slow that inexorable progression.

Simply going barefoot is not the answer. For those with significant physical deformity who are most in need, the artificial shoe heels have become an essential structural prop for them, and removing it leads to a further physical collapse in bilateral symmetry. There are no known simple, general answers now.

It is therefore urgent that we, for the first time, focus on the true cause – elevated shoe heels – of this global mass epidemic of modern human deformity, with its untold level of cost and misery, and on finding effective treatment for the direct effects of that cause, rather than blindly continuing the mere treatment of its multitude of seemingly unrelated symptoms.

In summary, the modern human body has been deformed – artificially by footwear, rather than preordained by genetics – resulting in unnaturally exaggerated anatomic differences between genetically diverse human populations and also between genders. And strictly by happenstance through the routine work of cobblers and their modern equivalent, all still entirely ignorant of the enormous negative impact of elevated shoe heels.

The evidence clearly points directly to a completely new and different understanding of what is normal in human anatomy, despite the conventional wisdom that gross human anatomy is the most settled of all the sciences.

How the everyday shoe manages to create such widespread deformity in every part of the modern human body is the focus of my new book. What is already known, and the research effort urgently needed now, are outlined there. A first draft of the both abridged book and the complete book are available at my website, **www.AnatomicResearch.com.**

Research Note:

I should also include here a note about the extent of my research effort. I have conducted over a period of many years a comprehensive analysis of all peer-reviewed research I could find in many different disciplines like biomechanics, anatomy, orthopedics, podiatry, physical anthropology, archeology, and many others that were related to shoe heel-induced supination, including many articles available only at the Library of Congress and the National Library of Medicine, not online. The **Endnotes** of my unabridged book now totals over 73 pages, mostly listing the many peer-reviewed articles I reviewed and concluded were relevant, and specifically noting the exact pages and/or specific figures that were considered most relevant. Far more articles were reviewed and deemed not sufficiently relevant to include.

LIST OF FIGURES

Introductory Figure **Figure 10.183** from ***Sarrafian's Anatomy of the Foot and Ankle***. Third Edition. Armen S. Kelikian, Ed. (2011), Lippincott Williams & Wilkins. Adapted from Hicks, J. H. (1961) The three weight-bearing mechanisms of the foot. In: Evans, F. G. ed. ***Biomechanical Studies of the Musculo-Skeletal System.*** Springfield, IL: Charles C. Thomas.

Figure 1A & 1B Different bare footprints of shoe-wearing European and barefoot Solomon Island native from **James**, Clifford S. (1939). Footprints and feet of natives of the Solomon Islands. In ***The Lancet***: 2: 1390-1393.

Figure 1C Lawrence H. **Wells** (1931). The Foot of the South African Native. In the ***American Journal of Physical Anthropology***, Vol. XV, No. 2. 186-289, **Figure 6** on **page 225**.

Figure 1D Adapted from **Figure 8.5** of ***The Running Shoe Book*** by Peter R. **Cavanagh** (1980).

Figure 1E Adapted from Figure 1 from **de Cesar Netto**, C., Bernasconi, A., Roberts, L., Potin, A., Lintz, F., Saito, G. ... O'Malley, M. (2019). Foot Alignment in Symptomatic National Basketball Association Players Using Weightbearing Cone Beam Computed Tomography. ***The Orthopaedic Journal of Sports Medicine***, 7. 2, 2325967119826081 DOI: 10.1177/2325967119826081

Figures 2A & 2B Comparative views of the European and Australian Aborigine tibial plateaus (lower surface of the knee joint) from W. Quarry **Wood** (1920). The Tibia of the Australian Aborigine. In the ***Journal of Anatomy*** Vol. LIV: Parts II & III (January and April): 232-257, Figure 1 on page 235.

Figure 2C Top views of tibial plateaus (middle photos) from India from Figure 2, page 139, from Kate, B. R. & Robert, S. L. (1965). Some observations on the upper end of the tibia in squatters. In the ***Journal of Anatomy***, Lond. 99: 1: 137-141.

Figure 2D View of ancient Roman tibial plateau from *Roman Catacomb Mystery*, **NOVA PBS** (air date 2/5/14).

Figure 2E A typical modern tibial plateau of right knee showing asymmetrical and malformed meniscus cartilage on the left, forward of the knee, based on Figure 349 of *the* ***1918 Edition of Gray's Anatomy****.*

Figures 3 A&B A rear view still photo frame of a Bushman (A) and Shod Finn (B) from a **YouTube** video clip of Barefoot running Bushman versus me (shod Finn) https://www.youtube.com/watch?v=H1Ej2Qxv0W8. Published on May 26, 2013.

Figure 4 Roger Bannister crossing the finish line as he broke the 4-minute mile barrier on May 6, 1954, by Associated Press.
Figures 5A-B Plate 23 Man Running, Frame 4 & 10, rear view at midstance, from Muybridge, Eadweard (1887). **The Human Figure in Motion**. New York: Dover Publications, Inc. (1955).
Figure 5C Composite of previous Muybridge Frames 4 and 10 of Plate 23 above with pelvis leveled in order to show the true relative e position of the flexed legs at the maximum weight-bearing load in the midstance position.
Figure 6A Figure 6A is Elevated shoe heel elevating the wearer's foot heel and thereby plantarflexing the ankle joint, based on Figure 290 *of* the classic 1918 Edition of Henry ***Gray's Anatomy of the Human Body***, available online at www.Bartleby.com/107/. Fig. 2B is from unknown web source*.*
Figure 6B Based on Figure 290 of the ***1918 Edition of Gray's Anatomy*** *and a*dapted from Hicks, J.H. (1961) The three weight-bearing mechanisms of the foot. In: Evans, F.G., ed. ***Biomechanical Studies of the Musculo-Skeletal System****.* Springfield, IL: Charles C. Thomas. Also from Kelikian, Armen (2011). ***Sarafian's Anatomy of the Foot and Ankle***, page 620. Philadelphia: Wolters Kluwer.
Figure 6C Adapted from Figure 10 of Kirby, K., Loendorf, A., and Gregorio, R. (1988) Anterior Axial Projection of the Foot. ***Journal of the American Podiatric Medical Association*, **78 (4), 159-170, which is from Root, M.L., Orien, W.P., and Weed, J.H. (1977). ***Normal and Abnormal Function of the Foot***, Clinical Biomechanics Corporation, Los Angeles and on Figures 16 and 20, pages 61 and 67, from Sgarlatto, T. E. (Ed.) (1971). ***A Compendium of Podiatric Biomechanics****.* San Francisco: California College of Podiatric Medicine.
Figure 6D&E Comparison between barefoot and heeled shoe of the path of the ankle joint (talar trochlear) when rotated externally to the outside by shoe heel-induced supination of the subtalar joint, based on Figures 244 and 258 of the ***1918 Edition of Gray's Anatomy****.*
Figure 7 Figure 3.2 based on Plate 18 Man Running, Frame 10 side view, from Muybridge, Eadweard (1887). ***The Human Figure in Motion.*** New York: Dover Publications, Inc. (1955).
Figures 8A&B Perspective view of body weight forces during running on the lower leg tilted to the outside, based on a part of a figure from ***De dissectione partium corporis humani libri tres*** by Charles Estienne. Paris, 1545. Simple graph of the force vectors of Fig. 8A.
Figure 9 Modified **Leonardo De Vinci** sketch known as "***The Vitruvian Man***" (c. 1485), showing the abnormal, unnatural general cross-over structural position of modern legs and hip joints, as well as showing the effect of the unstable pelvis, which results in a bent-out spine and tilted-in head.
Figure 10A&B Comparative upper surfaces of the talus (ankle joint) of an Egyptian and a European, Figure 61, page 114, of Jones, Frederic Wood (1949*).* ***Structure and Function as Seen in the Foot.*** London: Bailliere, Tindall and Cox.
Figure 10C Cone-shaped trochear surface of modern ankle bone, the talus, modified from an upper view of the talus in the ***1918 Edition of Gray's Anatomy.***
Figure 10C1 The trochlear surface of an ancient Anglo-Saxon talus, from Cameron, J. (1934). ***The Skeleton of British Neolithic Man*.** Williams & Norgate, Ltd., Fig. 29 and Plates XXX & XXXI.
Figure 10D Frontal plane cross sections of the ankle bone (talus) showing trabecular over-development of lateral side, Figs. 23.28-29 from page 273 of Michael C. Hall (1966). ***The Architecture of Bone.*** Springfield, Illinois: Charles C Thomas.
Figure 10E Frontal plane cross sections of the ankle bone (talus) showing trabecular under-development of lateral side, from Figure 34 of R. B. Seymour Sewell (1906). A Study of the Astragalus. In the ***Journal of Anatomy and Physiology*** 42:152-161, particularly Fig. 34 on page 160.

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