FIRST DRAFT 8/21/19

HIDDEN IN PLAIN SIGHT:

Elevated Shoe Heels Have Deformed The Entire Modern Human Body

Personal Background as the First Inventor of Shoe Soles Based on the Sole of the Barefoot

By way of introduction, I am a runner. To be more accurate, I am now, sadly, like the vast majority of longtime runners, little more than a former runner. At a relatively early stage in my running career, I developed an assortment of injuries, and these recurring injuries forced me to search for effective treatment.

Initially, of course, I was just looking for solutions for my own persistent problems, and I became frustrated by my inability to find existing running shoes or orthotics that resolved my problems. Eventually I put this frustration to good use. In 1988, I pioneered the first research and development on barefoot sole-based designs for shoe soles.

At that time, I discovered that the human foot, by itself, has far better lateral or side-to-side stability than when it is "assisted" by conventional shoe soles. My goal was therefore to invent a new shoe sole structural design that retained that vastly superior stability of the foot when bare.

The barefoot designs I developed at that time preserve in a shoe sole the wider, rounded shape and flexibility of the natural human foot sole. My immediate goal at that time was to prevent ankle sprains, which is the most common sports injury (as well as the most common cause of Emergency Room visits).

After about three years I was awarded my first U. S. patent, and many more patents followed, including foreign patents, for new shoe sole inventions based on the barefoot sole. (All of my now more than seventy-five footwear and footwear-related U. S. patents are listed on my website: www.AnatomicResearch.com. As a matter of fact, I am the most prolific U.S. inventor of footwear sole technology by a wide margin, with over 50% more U.S. patents in the modern era since 1970 than any other inventor, including those at the largest athletic footwear companies like Nike and Adidas.)

A Patent License with Adidas for Barefoot-Based Shoe Sole Technology

Three years later, in 1994, I licensed that patented technology to Adidas. Adidas dubbed the resulting footwear "***barefootwear***" during the initial product development phase. Barefootwear quickly became Adidas' core shoe sole technology in all categories of new footwear (but excluding classics, which are old models that are still popular, like the Stan Smith tennis shoe).

Adidas began marketing my shoe sole technology in 1996 as "***Feet You Wear.***" They used their star athlete endorsers, including Kobe Bryant (before he went to Nike) and their largest ad campaign to that date. Steffi Graff used the first ***Feet You Wear*** tennis shoe to win the U.S. Tennis Open in 1996.

By 2003, Adidas had marketed about a hundred different models of ***Feet You Wear*** and similar shoes, including many models in every footwear category. At that time, the patent license was terminated after several years of litigation over its terms.

Since then my focus has shifted. For many years I have been investigating an entirely different aspect of footwear design. My current research concentrates on the deforming effect on the human body of elevated heels in all forms of footwear, from athletic shoes to high heel women's shoes. This research is informed by the fact that elevated shoe heels, despite their modern ubiquity, are a major structural departure from the natural design of the human barefoot.

My Inadvertently Unique Investigative Approach

If you just follow the evidence wherever it goes in an investigation, you may end up in a completely unexpected place. That is what happened here.

Just following the evidence led me far beyond footwear sole design. Following the evidence forced me naturally to become deeply immersed in related parts of both biomechanics and anatomy (human, primate, and other animals), as well as paleoanthropology, physical anthropology, evolutionary biology, archeology, medical science (particularly orthopedics), podiatry and sports science (and even including computer and network technology, including hardware, software, and cybersecurity).

I was completely unaware as I was doing it that this kind of investigative approach has become totally unique. Modern science and industry is done exclusively by specialists who live and work almost entirely within their own narrowly defined specialty silos. Each of those silos exists within the larger walls of the overall professional field in which the specialists were educated and trained, and from within which few venture very far.

The old saw about academics, that they know more and more about less and less, seems to fit. More critically, the specialists only consider evidence from within their own fields and tend to discount and ignore the potential relevance and importance of evidence from related fields. This narrow focus leads inherently to blindness of another common sort: the inability to see the forest for all the trees.

By ignoring all of these artificial institutional boundaries I have, for example, stumbled into a wealth of very old but highly relevant evidence from the field of physical anthropology that are unknown in the fields of biomechanics and anatomy. Other examples are endless.

Investigating a Puzzling Effect of Elevated Shoe Heels

This investigation started as an informal attempt to answer a single question. It arose from a chance observation I made decades ago about the common shoe heel's puzzling effect on the human body, or at least on my particular body.

Over many years, however, the original investigation slowly evolved into a major endeavor aiming to solve an increasingly complicated anatomical mystery. My research has encountered various hidden twists and turns, as well as numerous dead-ends, and some very old clues, the importance of which - in hindsight - now seem obvious.

As I unwound the anatomical mystery to its logical solution, the unlikeliest of suspects emerged as the culprit – the elevated shoe heel and its biomechanical effects, which have been almost completely overlooked. The shoe heel has deformed the entire modern human body, from head to toe, and has done so almost invisibly. Although this seems incredible – even preposterous – all of the weight of the best available evidence clearly points to this shocking conclusion.

In effect, shoe heels have caused artificial human evolution in reverse. The article that follows reveals how commonplace and thoroughly innocuous shoe heels manage to accomplish this extraordinary feat. The article provides a brief overview of far more extensive research detailed in my new book on the same subject (I cite the book and provide a website link at the end of this article).

My research firmly supports the conclusion that elevated shoe heels have reshaped modern human bone structure and thereby eroded the ability of the modern human body to function naturally. I have based my research on a solid foundation of settled science, including many hundreds of peer-reviewed articles from the best medical and scientific journals from many different fields. They are all cited in an unusually extensive Endnotes section (which highlights the most relevant pages and figures of referenced articles).

The First Clues

A good mystery often plants an apparently innocuous clue near the beginning and the unsuspecting reader overlooks its importance until near the story's end, when the clue's central importance in solving the mystery is a sudden surprise. This particular case likewise begins with a pair of clues that have gone unnoticed for a very, very long time.

Many classic mysteries involve fresh footprints at the crime scene, but by a peculiar coincidence the first clues in this case are also footprints. These footprints, however, are not fresh. They have been buried in a long forgotten medical journal report since 1939.

The trail begins in an unexpected place. Located at the Melanesian Mission Hospital in the South Pacific island of Malaita, Clifford James authored the report in the prestigious British medical journal, the ***Lancet***.[1] James's report provides the clearest evidence that I have found that documents the effect of footwear on the modern foot.

James's obscure and dated report, in other words, provides unique, early evidence of the damaging effect of shoes. His report furnishes us with valuable clues in resolving a fundamental mystery, the baffling cause of many human deformities. In this case, the mystery, unlike most popular mysteries, does not involve a murder. Nor is it fiction.

The mystery does, however, involve life and death. As a medical mystery, it implicates many real lives and many real deaths. It involves issues so widespread that it presumptively affects you, the reader, and your own life and death. In this article, I will try to unravel – step by step – the origin and progression of this mystery.

Starting with just the few footprint clues from James, we will uncover a shocking medical discovery: how many major human anatomical deformities somehow have remained hidden in plain sight for centuries, until now.

So, to start, take a look at the clues. The two sets of footprints of bare feet offer a crucial key to begin unlocking the mystery.

THE FIRST CLUE: Diverse Human Populations Have Virtually Identical Footprints

The **first set of footprints**, **FIGURE 1A**, superimposes two separate bare footprints on top of each other. The first footprint was made by a barefoot Solomon Islands native (dashed line) and the second print by a European (solid line). Both had never worn shoes (which of course makes the European a very rare laboratory specimen). Although from different individuals, the footprints are essentially identical.

FIGURE 1A provides unique evidence that genetic distinctions do not determine the natural, inherent shape of the human foot. Both genetically diverse feet were the same, and both never wore shoes.

Because Caucasians and Polynesians demonstrate the same fundamental foot shape if allowed to develop without the influence of footwear, these identical footprints indicate that all human feet will have the same basic form.

THE SECOND CLUE: Normal Shoe Use Creates a Different Footprint

The **second set** of footprints, **FIGURE 1B**, superimposes another two bare footprints on top of each other. Again, the first footprint was made by a barefoot island native (dashed line) and the second print by a European (solid line), but this time a different European (in yellow), one who normally wore shoes in everyday use. This time the bare footprints are very different.

FIGURE 1B provides an essential clue: it demonstrates the critical impact of footwear on the human foot.

FIGURE 1B shows a critical change. The shoe-wearing European has a bare footprint (yellow solid-line) that is rolled unnaturally to the outside about **6°** relative to the natural barefoot footprint. Technically, this externally rotated foot position is called **supination** (in contrast to a rolled inward position, which is called pronation).

FIGURE 1B provides strong evidence that shoes – not genetics – have caused this difference in foot shape between the Polynesian native and the shod European, since their shoe usage is the only difference between the two footprints.[1]

The old footprints in the **James** study, in sum, provide definitive evidence that shoes alone will change the shape of the modern human foot. Genetic differences play no role in the distinction.

FIGURE 1C shows additional evidence from an African physical anthropology study in 1931 by Lawrence **Wells** that the shoe-wearing European heel bone (calcaneus) is tilted out or inverted about **6°** in the unnatural supination position, compared to un-tilted heel bones of the barefoot Africans. 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 and not in barefoot Africans, Bushman and Bantu, respectively (**B & C**).[2]

This study is less complete than the James study from the Solomon Islands, since it does not show the calcaneus of a European who has never worn shoes. It does, however, show how the supinated or tilted out position is actually baked into a structural portion of the shod-formed heel bone.

Note also the structural change apparent in the unnatural, excessive enlargement of the lateral calcaneal tuberosity (shown darkened) in the supinated calcaneus of the (**D**) European – probably due to the abnormal lateral tilt interacting with the elevated shoe heel to cause artificially increased pressure on a constant, repetitive basis – which is absent in the barefoot Africans (**B & C**). That same artificially increased pressure on the lateral, rearmost portion of the calcaneus also causes the characteristic wear pattern at precisely the same lateral, rearmost location on the bottom on the elevated heels of modern shoes.

This overlooked simple but direct evidence from James and Wells contradicts a widespread general belief that all human anatomical differences between humans with diverse genetic backgrounds are genetic differences determined by nature, not the inadvertent hand of man.

This new and more correct insight begs an important question: how exactly do shoes change the feet? Many studies before and since have implicated shoes as the prime suspect in the many well-known problems of the modern foot itself, including foot deformity and pain. But none of them show precisely how shoes do it.

So how do shoes change feet? What mechanism is involved? The footprint clues point to a specific direction our investigation can take as it begins in earnest.

We will first focus on the following question: why and how exactly do shoes cause the foot to roll to the outside in supination. That question is central to this investigation.

Some Background on Shoes and Running

To begin, we need a little background information on running and shoes. In 2004, Professors Dennis Bramble and Daniel Lieberman published a widely reported study in the respected scientific journal ***Nature*** that concluded that evolutionary forces had designed the human body to run[3].

Drs. Lieberman and Bramble presented compelling evidence that human beings were the best endurance runners in the animal kingdom. Humans excel at "persistence hunting" in which they successfully run down faster antelopes and other game in long hunts over great distances. Persistent hunters succeeded by becoming efficient runners: their bodies – unlike their prey - did not overheat. The bodies of these hunters, moreover, clearly evolved over hundreds of thousands of years to dissipate heat while their feet were bare.

In 2009, Christopher McDougall published his best-selling book, ***Born to Run***[4]. The book, which echoed the pioneering scientific work by Harvard professor Daniel Lieberman and others, offered evidence that the human body has evolved to run as its primary physical function and to do so injury-free without the aid of modern running shoes.

In stark contrast, since the 1970's, when running and jogging became widely popular, injury rates for running in modern running shoes have persisted unchanged at very high levels, consistently as high as 70% per year in repeated studies.

Around this scientific and medical data, McDougall recounted the true story of an incredibly tough 50-mile race in the rocky, hilly Copper Canyon of Mexico. An untrained, un-coached runner, a Tarahumara Indian, won this race wearing semi-barefoot sandals. This runner triumphed over the all-time-world's-best ultramarathoner, Scott Jurek, a modern Western champion who wore his favorite modern running shoes.

The book's publication generated almost overnight a revolution in barefoot running. Many runners began running barefoot or in more barefoot-like "minimalist" shoes such as the Vibram Five Fingers. Many of the leading biomechanics scientists involved in running shoe research and design announced publicly that it was time to begin from the start.

The impact of the barefoot running revolution, best described as a popular uprising against conventional footwear, stirred a reaction in the professional footwear science community that had been already been simmering for years. In 2005, one of its leaders and pioneers, Martyn Shorten, concluded that none of the footwear science research being published at that time was worth reading, and that there was no meaningful scientific progress on preventing running injuries despite many decades of work[5].

Another of its leaders and now elder statesman, Benno Nigg, observed in 2010 that they had been barking up the wrong tree for the last 30 or so years[6]. Dr. Nigg argued that groupthink had resulted too readily in too easily accepted dogma that produced increasing complex but similar footwear without proven benefit.

By 2011 another leader and early pioneer, E.C. Frederick, the Editor-In-Chief of ***Footwear Science***, concluded in an Editorial titled "**Starting Over**" that

> The fact that we can't answer many really fundamental questions about the functional benefits of shoes, not to mention their potential detrimental properties, ought to be humbling if not humiliating. Instead of responding with emotionally charged polemics … it's an opportunity, if not a clarion call, to start over.[7]

Dr. Frederick's "clarion call" to start over, however, has gone largely unanswered. The barefoot running revolution rather quickly fizzled out. The reason is simple: neither "minimalist" running shoes nor barefoot running have significantly reduced the high injury rates of runners. In reaction, "maximalist" running shoes have also come, but brought no significant improvement. And conventional running shoes have remained essentially unchanged.

The athletic shoe industry has arrived now at a major impasse with a serious recurring injury problem but no injury-reducing solutions on the horizon.

Can We Look to the Athletic Shoe Companies for an Answer?

Unfortunately, no. In 2008, Dr. Craig Richards authored a groundbreaking research paper on the design of modern running shoes[8]. In simple terms, his paper makes unequivocally clear that there is no published scientific evidence - none whatsoever - supporting any of the supposed benefits of modern running shoes and their many different technologies. The omission regarding injury reduction or prevention is critical, since running injury levels are remarkably high for a non-contact sport.

In his paper, Dr. Richards even challenged major footwear companies to provide supporting scientific evidence of the advantages of their footwear designs. No company has responded to his challenge, which strongly suggests there is none. Nor has any such evidence been published independently by other researchers.

As far as I know, the actual research done in-house at footwear companies is totally focused on going faster and jumping higher, not injury prevention or reduction. Virtually all of their research is treated as trade secrets, except in the most general terms, so there is no public information available on the scientific basis for the advantages of any of their footwear products.

The only exception I know of is some recent semi-public research by one company that attempts to support a performance advantage of a new sole technology without being able to specify which of its structurally different components produce the alleged advantage or how they interact, and while also ignoring completely any potential for increased injury levels caused by that new technology.

Only their advertisements are public, and those ads are legally prohibited from making footwear claims that have not been proven scientifically. Lack of proof may explain the absence of any such footwear ad claims, even for what obviously would appear intended to be "technical innovations" (of which there are countless examples).

Worse, most existing peer-reviewed studies on running and shoes published by the academic scientific community use a relatively small number of test subjects, which, of course, severely limits the statistical validity of the studies.

Also, none of the existing running studies of adults (who are the subjects of virtually all such studies) use randomly selected test subjects. That critical failure makes all of their results scientifically no better than anecdotal at best and, at worst, false and misleading.

Instead, all running studies use active runners, who obviously self-select themselves by running actively. Those active runners represent only a small part of the total human population, the vast majority of whom are non-active, former runners who may have run only in childhood. As a result, at present we know nothing about the running biomechanics of most of the modern human population or about the biomechanical effects of modern running shoes on that population when running.

Finally, only a few studies of very limited scope have used test subjects that are barefoot runners who have never worn shoes. This article will discuss these general running research flaws more extensively at the end of Endnote 11.

Never-Ending 70% Annual Injury Rates Look Inevitable Because No Running Shoe Designs Offer a Potential Solution

At this point, all runners, active and former, are now hopelessly trapped in a dead-end. The footwear industry has failed to develop any viable new alternatives to try, only old ones to recycle. If we were born to run, why does running cause so many injuries that most active runners are forced to quit?

As this article will demonstrate, a solution to the injury problem requires a new and different understanding of modern human anatomy and biomechanics. The most important variable in the basic equations of those sciences has not even been considered.

As you read on, remember the simple evidence previously shown in **FIGURE 1B**, namely, that conventional **shoes cause feet** to **supinate** abnormally or **to roll unnaturally to the outside**. That clue becomes the key that unlocks the mystery that is uncovered in this article.

Actually, This Hidden Clue Should Not Be a Surprise, Because It Follows Directly From Well-Known Sciencific Evidence

It is obvious that the effect of the elevated heel of a shoe is to place the ankle joint of the wearer's foot into a plantar-flexed position. It is well-known in biomechanics that plantar-flexion supinates the subtalar joint, an effect that is critical to toe-off propulsion during locomotion. The subtalar joint plays the controlling role during human locomotion in converting the load-bearing foot from flexible for the support phase of stance into rigid for the propulsion phase of stance **(see FIGURE 1F)**.

This widely-recognized biomechanism principally involves the windlass effect, as described by J. H. Hicks, and the foot, ankle and subtalar joints, specifically their structure and function. Many recognized researchers, past and present, so numerous it is not practical to list more than a few among the many of the earliest and most relevant of them, have thoroughly researched this scientific evidence which directly supports the reality of the plantarflexion/subtalar joint coupling.[8A]

Oddly, only the elevated shoe heel's role as the artificial trigger of the coupling has been overlooked. Since overwhelming supporting evidence has already been discovered, it is therefore not hypothetical, but rather a biomechanically inescapable conclusion that the elevated shoe heel, by the simple fact of causing plantar-flexion, also automatically causes the wearer's subtalar joint to supinate.

Indeed, simply put, it seems impossible to avoid the conclusion that the elevated shoe heel is biomechanically coupled to subtalar joint supination. Nevertheless, that apparent fact has seemly escaped notice before now.

The Automatic Reaction of the Ankle Joint to Elevated Shoe Heels

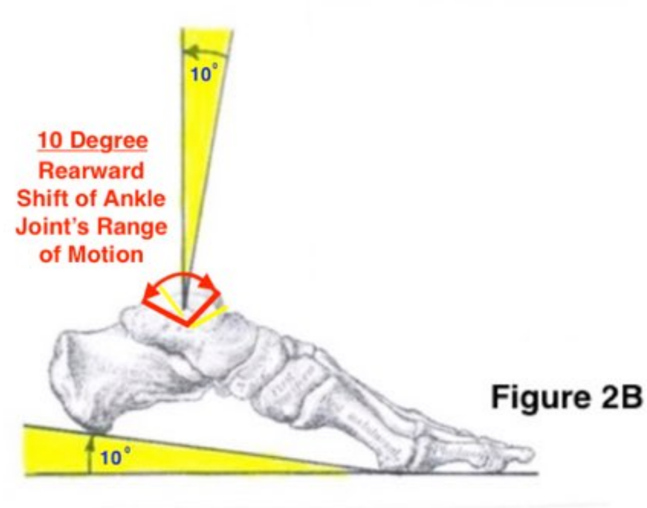
The principal lower leg bone is the shinbone or tibia. The shinbone is joined (with the fibula) to the ankle bone or talus to form the ankle joint. The ankle joint is a simple joint that works mechanically like a hinge. Its structure and function are easy to understand.

So too, an elevated shoe heel inserted under a heel of a human who is standing upright and stationary causes a fairly simple and automatic direct reaction by that human. In order to maintain balance in the same upright stance, a person unconsciously and automatically straightens their leg from the bent forward position caused by the elevated heel.

The shinbone automatically moves backwards in an amount equal to the amount by which the elevated shoe heel tilts the foot downward. Without this semi-automatic reaction, a person would fall forward uncontrollably. See **FIGURES 2A&B.**

In other words, if the elevated shoe heel raises the foot heel and tilts the foot downward by **10°**, then the shin bone must move backwards on the ankle joint by **10°**. This semi-automatic adjustment maintains the same upright, straight leg standing position. It is a simple and almost automatic bio-mechanism, a compensation that places the ankle joint in a plantarflexed position.

See **FIGURE 2B.**



This semi-automatic, self-adjusting ankle joint reaction to the elevated shoe heel is so straight-forward as to be obvious. However, well-hidden underneath the simple ankle joint is a much more complicated joint reaction to the elevated shoe heel.

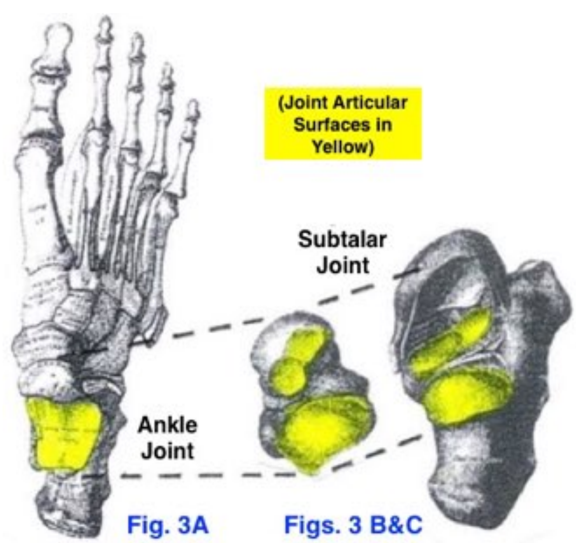
And, most critically, this **10°** shift backwards of the ankle joint's range of motion has a hidden but enormous effect on the subtalar ankle joint, altering its biomechanical function and making it abnormal, as we shall soon see.

Shoe Heels Critically Affect the Subtalar Joint, Which Is Under the Ankle Joint

FIGURE 3A shows the foot's main ankle joint. The part of the upper surface of the ankle bone or talus forming the ankle joint's articulating surface is shown in yellow.

Directly underneath the ankle joint is the subtalar joint, with the articulating surfaces also shown in yellow in **FIGURES 3 B&C**).

The subtalar joint is located between the bottom of the ankle bone or **talus** and the top of the heel bone or **calcaneus**. A lower part of the talus forms the upper articulating surface of the joint (the talus is shown upside down in **FIGURE 3B**), and an upper part of the calcaneus forms the lower articulating surface of the subtalar joint (**FIGURE 3C**).



As the side-by-side comparison demonstrates, the subtalar joint has a far different and more complicated structure than the ankle joint and a different function.

The elevated shoe heel directly affects the subtalar joint. However, the effect is different than that of the ankle joints, because of the subtalar joint's more complicated structure and function.

The subtalar joint does not need to operate in the same way as the ankle joint because the ankle joint already provides the simple hinge joint necessary to allow the shinbone to move forwards and backwards over the foot.

The subtalar joint has a different function. It provides for sideways or left to right motion of the foot on the ground. This capability for side-to-side motion is essential. It permits the foot to adapt to irregularities in the ground surface during locomotion.

The subtalar joint also has another, less obvious function. It is an essential component of a locomotion system that controls the rigidity of the foot. This rigidity control is critical to enable the foot to fulfill two basic but opposite functions while walking or running.

The Subtalar Joint Enables the Foot to Alternate Between Flexible and Rigid

Pronation Provides Flexibility During the first half of the stance phase after landing when running, the foot must be **flexible** to enable it to absorb the shock of a ground reaction force about two-to-three times our full body weight when we land and, at the same time, the foot must quickly adapt to the shape of the ground.

The subtalar joint performs this dual, contradictory role by enabling a sideways rolling motion of the foot on the ground. The foot's sideways rolling motion is called **pronation** when it rolls to the inside in order to use its increased flexibility to absorb landing shock.

During pronation, the main longitudinal arch of the foot depresses toward the ground, and the heel bone tilts inward, from its neutral, almost vertical position. During this first half of the stance phase when running, the heel bone – which forms the base of the subtalar joint -- is load-bearing on the ground.

Supination Provides Rigidity During the second half of the stance phase, the foot must become **rigid** so it can function as a propulsive lever to push off the ground, propelling the body forward.

The foot's sideways rolling motion to the outside or supination creates a more rigid propulsive lever. During supination, the main arch is raised and the foot moves into a plantarflexed position, creating a rigid propulsive lever.

The heel bone tilts outward from the neutral, vertical position as the heel is raised prior to the toe-off phase of propulsion. At this point of the running stride, the heel bone is off the ground and no longer load-bearing, with all of the runner’s body weight shifted forward to the forefoot.

This rigid propulsive lever is unique to the human foot. Chimpanzees, our closest living non-human relatives, do not have it.

The Effect of Elevated Shoe Heels on the Subtalar Joint Has Not Been Well Understood Before Now

The subtalar joint's role in pronation and supination motion has long been well understood. However, a direct consequence of this well-known bio-mechanism has been overlooked. This overlooked consequence is that **the elevated shoe heel by itself automatically causes the subtalar joint to roll the foot slightly to the outside in supination**.

As a result of the shoe heel-induced supination motion, the heel bone artificially tilts out and the foot also becomes more rigid. And this unnatural bio-mechanism happens when the heel bone is load-bearing on the shoe heel on the ground. In a literal sense, this is a pivotal change.

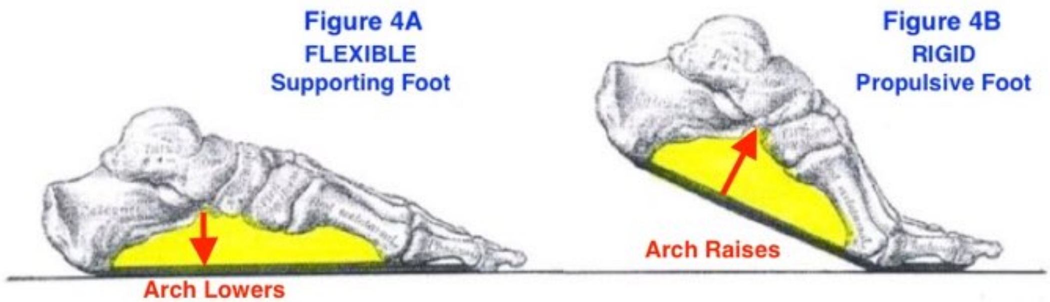
When the body stands upright, the foot is no longer in a natural, neutral position. It is in a more rigid, plantarflexed position, tilted unnaturally to the outside.

If the height of the elevated shoe heel is moderate, then the associated tilting-out and rigidity of supination is also moderate. If the height of the elevated shoe heel is greater, then the degree of tilting-out and rigidity of supination will also be greater.

This supination adjustment of the foot in reaction to an elevated shoe heel is an automatic bio-mechanism - a direct function of human foot anatomy and biomechanics. It primarily occurs for two reasons.

FIRST: The Natural Windlass System (Shown Without Shoe Heels)

Flexible Phase A powerful ligament called the plantar aponeurosis (located on the bottom of your foot sole and



shown as the thick black band in the figure below) connects your heel bone to your toes. When the foot is flat on the ground, the plantar aponeurosis is relatively loose, so the foot is therefore flexible enough to conform to any ground surface irregularities and still provide a stable base of support for the leg. **FIGURE 4A** shows the position of the flexible supporting foot.

Rigid Phase When the heel bone is raised during the propulsive phase of running or walking, the forefoot remains on the ground, automatically bending up the toes relative to the rest of the foot. This bio-mechanism automatically tightens the plantar aponeurosis so that **it acts mechanically like a windlass** that forces the foot into a supinated position, with both a higher, more rigid arch and a tilted outward heel bone. This bio-mechanism transforms the foot into a rigid propulsive lever enabling it to push off when running, jumping, or walking. See **FIGURE 4B**, which shows the position of the rigid propulsive foot.

The elevated shoe heel – by simply raising the heel – thereby artificially and unnaturally forces the foot into this supinated position all the time – including throughout the entire load-bearing phase -- not just during the toe-off propulsive phase of running or walking.

SECOND: Elevated Shoe Heels Automatically Rotate the Position of the Subtalar Joint to the Outside

A midtarsal joint connects the heel and ankle bones with the middle part of the foot (called the midtarsal of the foot). The windlass action of the plantar aponeurosis pivoting around the metatarsal joints acts as a locking mechanism for the midtarsal joint.

When the elevated shoe heel is automatically plantarflexes the foot, the windlass action supinates it. This supination raises the longitudinal arch and gradually locks the midtarsal joint into an ever more rigid supinated position, away from a pronated position. The human foot thereby becomes a rigid propulsive lever.

The Subtalar Ankle Joint's Range of Motion (Front View of Right Ankle & Heel Bones)

FIGURE 5A shows a front view of the ankle bone (talus, in yellow) and underneath it, the heel bone (calcaneus). The subtalar joint joins them both together. **FIGURE 5A** shows the operation of the subtalar joint. The ankle bone rotates on top of the heel bone – tilted inward in PRONATION and tilted outward in SUPINATION.

Each of the midtarsal joints connecting the front of the ankle and heel bones to the rest of the foot have a joint axis. In the SUPINATED position, the joint axes are crossed, locking the joints in order to make the foot rigid for propulsion. In PRONATION, the joint axes are parallel, unlocking the subtalar joint. The windlass mechanism synchronizes the position of the subtalar joint with the position of the ankle joint.

Both the windlass action of the plantar aponeurosis and the locking role of the midtarsal joint have been very well known in the associated fields of anatomy and biomechanics for many decades, as is their mutual interaction with the subtalar joint to form an effective part of the human locomotion system. The bio-mechanism is settled science.

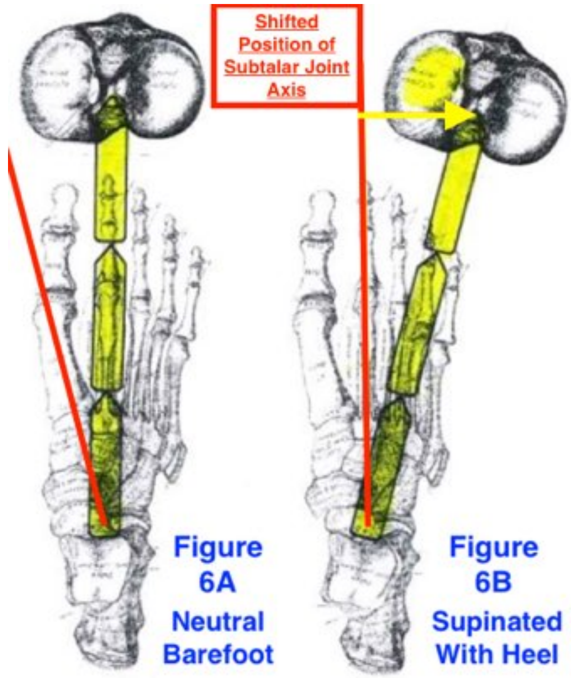
Foot Supination Automatically Rotates the Lower Leg (Tibia) to the Outside

A different bio-mechanism is also settled science. Any foot supination motion, such as that caused by the elevated shoe heel, automatically rotates the lower leg (principally the tibia) to the outside, as demonstrated in a classic study by Gustav **Rubin**[9]. **FIGURE 5B** illustrates this bio-mechanism in which foot motion is coupled to lower leg rotation in a directly mechanical way.

Foot Supination Automatically Also Twists the Knee to the Outside

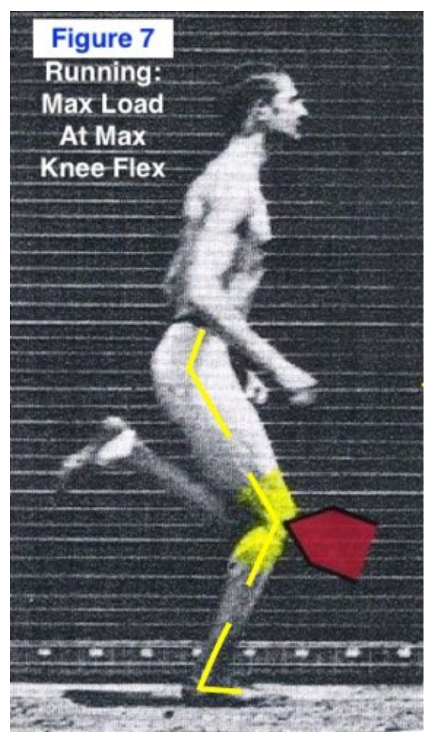
FIGURE 6A shows a natural, unshod right foot and the natural, un-twisted right knee position pointed straight ahead in the flexed-knee midstance running position. The ankle joint is pointed straight ahead and the knee joint is flexed to absorb the full force of body weight when walking and especially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

FIGURE 6B, in contrast, shows the unnatural, maximally loaded, tilted out right knee position caused by an elevated shoe heel when walking and especially running, also at the maximally loaded midstance position of **FIGURE 7**. The outwardly rotated ankle joint forces the knee to twist to the outside. **FIGURE 6B** 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.



It is significant to note also that the subtalar joint axis (approximately shown in **FIGURE 6B** as a **red line** – located about 15° medial to the long axis of the foot) has been shifted externally in the horizontal plane, so that it is essentially aligned with the long axis of the foot when running – resulting directly from the outward movement of the three-dimensional position of the supinated foot's subtalar joint caused by calcaneal inversion in the frontal plane. This aligned position of the midstance running position of the subtalar joint axis contrasts with the subtalar joint axis being internally rotated relative to the long axis of the stationary foot, as described in the classic work of Merton Root et al.[10]

It is critical to understand that when the foot is load-bearing on the ground during running, the physical position of the subtalar joint and its axis are always moving in all three planes as the calcaneus (which forms the lower surface of the subtalar joint) constantly rolls inward and outward in eversion and inversion on the ground (or on the upper surface of the shoe sole).



A Runner's Knee: Unnaturally Twisted & Tilted When Maximally Flexed & Maximally Loaded

Running plays a decisive role in producing abnormal structural change caused by shoe heels. The change results when an abnormal twisted-outward foot forces the knee to likewise twist-outward while flexed about **40°** at the maximal load-bearing point during the midstance phase of running shown in **FIGURE 7**. The greatest repetitive load on bones and joints occurs then, at about two-to-three times body weight.

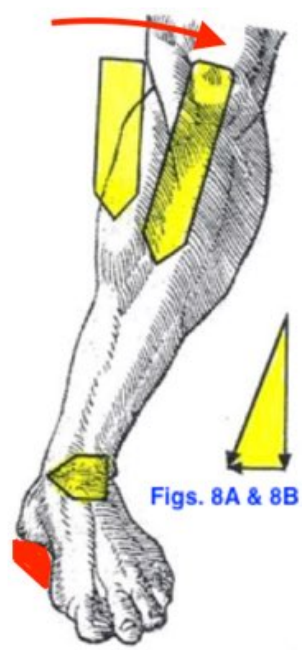
This maximal repetitive load is critical in altering the natural development of bone structure. According to Wolff's and Davis' Law, bone and joint formation including ligaments occurs in reaction to the loads to which the bone is routinely subjected. For the human body, the peak routine body weight load occurs when running, especially during the childhood growth phase, when running is a constant activity. (One of the most frequent parental commands is either "Don't Run!" or "Stop Running!"- both of which children usually ignore.)

FIGURE 7 shows a typical midstance running position at peak load-bearing. **The runner repeatedly experiences a peak load of 2-3 times full body weight alternately on his right and left knees when flexed about 40°. The ankle joints are dorsiflexed about 25° and the hip flexed about 50°.** In contrast, the typical walker's load-bearing leg is relatively **straight** when it passes directly underneath the walker and bears only **the walker's one full body weight**. This greater difference when running – two-to-three times greater load – is critical in bone formation during childhood and adolescent growth.

The bones of the human body are formed and modified in reaction to the peak loads the body routinely experiences in childhood in this flexed knee, hip, and ankle joint running position.

This cannot be overemphasized, since it has not been recognized before now: FIGURE 7 shows the principal position in which the bones and joint structures of the modern human body are actually formed: naturally flexed, not upright – but abnormally twisted by elevated shoe heels, not straight. The human body was born to run in this peak load position, optimized for it, but not to be maximally twisted by shoe heels in this position.

Incidentally, the footprints clues cited in the James report (**FIGURES 1 A&B**) are all the more valid as evidence because the footprints were taken with knee bent forward, forced down, so that a single leg supports by the individual being measured. James' footprints therefore roughly reflect the typical midstance running position shown in **FIGURE 7** above (although only with a load of about one full body weight, rather than the two to three times full body weight typical in running).



Figs. 8A & 8B

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 during peak dorsiflexion shown previously in horizontal view of **FIGURE 6B & 7**. 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**.

It has been well documented in running biomechanics for many decades that the lower leg has a nearly constant varus (out-tilted) angle of about **8°**, varying only about 1°-2° (from 6°-10°) during foot contact with the ground.[10A] This position is so contant it has been used by leading researchers as a neutral baseline from which to measure rearfoot inversion/eversion during running (supination/pronation are also to describe this tilting out/tilting in motion of the heel).[10B]

As a result, the nearly constant 8° varus angle of the lower leg creates a horizontal force component at the ankle joint that is directed internally or medially (this biomechanical action was described by Peter Cavanagh and is summarized later relative to **FIGURE 1D**).[10C]

More recent research has confirmed these earlier results. For example, as study by Radzak et al. has reported an average of about 8° lower leg position at peak load with the knee in maximum flex.[10D] Similarly, McClay reported about 7 of lower leg varus.[10E]

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 medial horizontal force vector component is critical. It unnaturally forces the ankle joint inward, thereby causing the calcaneus to evert inward unnaturally and depressing the medial longitudinal arch.** If the runner's leg remained naturally vertical, there would be only a vertical force vector, with no horizontal component vector.

If the lower leg inversion or varus of about 8° is caused by the shoe heel-induced supination of the subtalar joint of about 6°, what is the lateral horizontal force component caused by that subtalar joint supination? A recent study of 25 runners by Zifchock et al. has supplied an answer, which is about 4% of the peak ground reaction force (GRF) during running midstance.[10F] An earlier study by Nigg has a similar result.[10G]

Since the medical horizontal force component is generated in direct compensation for the lateral horizontal force component generated by the elevated shoe heel, it should also be about 4% of the GRF. The Zifchock study reported about 2300 N for average GRF, so the lateral and medial horizontal force components should be about 90 N. The medial horizontal force component of about 90 N acts directly on the inverted talus by the inverted tibia, pushing the talus internally, artificially pronating the subtalar joint and everting the calcaneus.

Moreover, these two forces do not directly opposite each other, but rather are substantially offset. The medial horizontal force component is directed to the subtalar joint, whereas the GRF is generated between the bottom surface of the shoe sole and the ground it contacts during stance.

Consequently, a moment arm is formed between the subtalar joint and the bottom surface of the shoe sole. Taking the example of a typical size 11M athletic shoe wearer, that moment arm would be about 8 cm, so that the resultant artificial torque or force moment acting medially on the subtalar joint would be about 7 Nm. If the elevated heel is higher, then the moment arm becomes greater, thereby increasing the resulting artificial torque the pronates the subtalar joint.

Remarkably, the available evidence indicates that **never-shod barefoot runners <u>do not evert</u> their feet** because they have untilted, vertical legs (as we will see later in an African Bushman (**FIGURE 17D)**, as well as the Bantus of South Africa. Lawrence Wells noted in a hundred page study that:

> …the most casual observer of the Bantu [the principal tribe of South Africa] cannot fail to be struck by the peculiar 'spongy' quality of their tread, which is apparent even in ordinary walking, but in running is greatly accentuated. …In the Bantu …**there is no eversion**, but the foot sinks down, as it were, 'on an even keel,' in consequence of *a flattening of the lateral arch*. …The settling down of the foot ends when the body is supported upon the heads of the first, second, *and fifth* metatarsals and on the medial tubercle of the calcaneus. [bolding added][10H]

Only runners who are exposed to longtime use of elevated shoe heels are forced to evert their feet unnaturally with every running stride!

Never-shod barefoot runners apparently only pronate to unlock the subtalar joint naturally and automatically after natural supination has occurred in the propulsion phase, when the foot must be rigid, in order to make the foot flexible during the landing and support phases. Such barefoot runners also pronate (and supinate) their subtalar joints as necessary to change direction and/or to accommodate to irregularities of the terrain (in the frontal plane) underneath their feet.

A natural, vertical leg is inherently in equilibrium. The vertical downward body weight force is balanced by a matching vertical upward ground reaction force. There are no de-stabilizing horizontal force components. In contrast, the unnatural shoe heel sets up a fundamental structural instability, as shown above in **FIGURES 8A&B**, due to an unnatural horizontal force component.

<u>THE UNNATURAL CAUSE: SUPINATION</u> In summary, as shown in **FIGURES 6B & 8A,** the structure of the elevated shoe heel unnaturally forces the knee to tilt <u>outward</u> 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 <u>action</u>.

<u>THE UNNATURAL EFFECT: REARFOOT (ANKLE OR CALCANEAL) EVERSION</u> Simultaneously, in compensation to the abnormal bow-legged position, the ankle and heel bone are unnaturally forced <u>inward</u> by an unstable horizontal force vector caused by the tilted lower leg, resulting in unnatural ankle or calcaneal eversion, as shown in **FIGURES 8A&B**. This is the <u>reaction</u>.

Simply put, the unnaturally <u>outward</u>-rotated supinated foot creates an <u>outward</u>-tilted lower leg that directly forces the foot to evert <u>inward</u> unnaturally in reaction.

Where the unnatural action and reaction forces balance in equilibrium for each leg of any given individual is dependent on that individual's personal body structure and on chance in the form of personal injury, the probability of which is unnaturally greater due to the unnatural instability.

The simultaneous dual interaction of unnatural action and reaction is **strictly biomechanical**. Caused by shoe heels, the action and reaction is automatic and unavoidable, even though it is both unnatural and artificial.

A Mysterious Anomaly: The Coupling of Foot Supination & Pronation to Lower Leg External & Internal Rotation Is Somehow Decoupled During Running

The static lower leg bio-mechanisms described above in **FIGURES 5A&B** are firmly based on settled science. For that matter, there is no debate about **FIGURES 1-7** nor have any substantive counter-arguments been raised relating to them by the many biomechanics scientists to whom I have given draft copies of my analysis.

However, many studies in recent decades indicate clearly that these static mechanisms break down when measured dynamically during running; that is to say, the mechanisms are "**decoupled**" when running.[10] I would like to formally thank Dr. Ned Frederick for emphatically pointing out this important issue to me in his reaction in 2017 to an early draft of my book in which I had not addressed decoupling directly.

More specifically, those running studies measured midstance eversion of the dynamic rearfoot and found that dynamic eversion produces much less internal tibia (lower leg) rotation than forecast by results from earlier stationary studies, such as those shown in **FIGURES 5A&B.** That significant reduction in expected tibial internal rotation during running provides clear evidence of the decoupling of the well-known static bio-mechanism.

To be clear, the biomechanical studies' use of the term "decoupled" is in itself misleading. Its English definition actually includes two conditions, either "to reduce or eliminate coupling." In the most common and original English usage, decoupled would tend to mean "not" coupled or "uncoupled", as in one train car being uncoupled from another.

But biomechanical coupling is not an absolute either/or coupling. In the above referenced studies, "decoupled" only means reduced but still directly connected. None of the studies - static, walking, or running – challenge the well-established biomechanical data that shows that foot supination/pronation is directly coupled to lower leg external/internal rotation.

The studies raise three issues. First, whether coupling – the ratio of foot motion to leg motion – stays the same or is reduced during different forms of locomotion, especially during running. Second, if the coupling ratio is reduced, then by how much. Third, and, perhaps most important, why does the coupling reduction occur in the first place?

The decoupling studies specifically have found that joint linkages - when measured while stationary - are relatively rigid relationships, but apparently become more flexible under dynamic conditions, since those conditions will reduce the ratio relationship between them. The studies therefore suggest that this known static bio-mechanism has less effect in a dynamic situation, perhaps much less.

Solving the Puzzling Decoupling Mystery

If these decoupling studies are correct, then all the effect of shoe heels on subtalar joints described earlier in this article would also decoupled when running, and would therefore produce a smaller effect, perhaps much smaller. That is potentially a significant issue, given the central importance of running to the analysis outlined above relating to **FIGURES 6B & 8A**.

Decoupling has remained an important riddle in a scientific sense, since no one knows why decoupling happens. A solution to the riddle is proposed here as follows.

During running, the elevated shoe heel itself -- as the automatic bio-mechanism described above in **FIGURES 6B & 8A** - directly causes the observed **decoupling** of the foot and lower leg bio-mechanism. A number of excellent peer reviewed biomechanical studies provide evidence for why this must be so.

Ankle Joint Decoupling During Running Is the Net Effect of Two Separate Torsions

When elevated shoe heels are used during running, the observed coupling between tibia and calcaneus is the net product of two torsions, one natural and one artificial, both acting at the same time in the same place - the subtalar joint.

First Torsion – Natural Coupling: The static lower leg coupling bio-mechanisms described above in **FIGURES 5A&B and 6A&B** naturally produce the first torsion. Those coupling bio-mechanisms – all of which would otherwise be expected from stationary testing - include the normal, well-proven internal/external rotation motion of the tibia in the horizontal plane and eversion/inversion of the foot in the frontal plane that would otherwise be expected from stationary testing, as shown by Rubin in **FIGURE 5B**.

Second Torsion – Artificial Decoupling: The structure of the elevated shoe heel itself artificially produces the second torsion. The automatic decoupling bio-mechanism described above in **FIGURES 2A&B and 4A&B** - caused by the elevated shoe heel - initiates an unnatural change in the first torsion. The result is the unstable, tilted-out lower leg position shown in **FIGURES 8A&8B.** The same decoupling bio-mechanisms shown in **FIGURES 5A&B and 6A&B** provide the basis for this second torsion and would otherwise be expected from stationary testing like that of Rubin.

The two torsions are offset against each other to produce a net torsion that determines the observed joint coupling during running by modern runners who have grown up in modern footwear.

Unfortunately, all of the running decoupling studies listed above in **Endnote 10** have failed to account for the presence of the elevated shoe heel-induced torsion. In my view, this omission is serious. The missing shoe heel-induced decoupling torsion is strictly based on settled science as described above, and all future studies must directly address its effect in order to produce scientifically valid results.

By ignoring the presence of the torsion effect of elevated shoe heels, these previous studies have simply interpreted the observed decoupling effect during running as an unexplained anomaly. This critical omission fails to correctly interpret the coupling during running as a net value of two torsions, one natural and one artificial.

Simply put, shoes heels directly cause the decoupling, and the decoupling substantially disrupts the otherwise direct joint linkages. To put it another way, **the observed decoupling is simply the direct structural effect of elevated shoe heels creating the inherently unstable lower leg structure shown in FIGURES 8A & 8B**.

Firm Research Support for Elevated Shoe Heel-Induced Unnatural Supination of the Modern Foot

Data from a recent biomechanical research study by Steffen **Willwacher** et al provides solid support for this conclusion. The study won the **Nike Award for Athletic Footwear Research**, the highest award presented in 2015 at the **XIIth Footwear Biomechanics Symposium** in Liverpool, UK, a biannual conference sponsored by the **International Society of Biomechanics.**

The unusually large number of 222 test subjects in the Willwacher study provides the data for a mathematical explanation of the actual physical existence of the artificial shoe heel-induced supination and its bio-mechanism acting to decouple the natural motion of the foot and lower leg**.** The mathematical explanation, although somewhat technical, is reasonably straightforward. A in-depth analysis is provided in lengthy **Endnote 11**.

A following is a simple and short summary of the main points of the full analysis: using extra diligence in conducting his experiment, Dr. Willwacher collected additional, unpublished data which he has kindly shared that his test subjects had an average of **4° of ankle inversion for males** and **5° of ankle inversion for females** while standing in their own running shoes (rearfoot or ankle or calcaneal inversion being the frontal plane measure of subtalar joint supination). By the way, Dr. Willwacher's **4°-5° inversion** seems close to the amount of supination shown in the **FIGURE 1** footprint we started with.

If you just make the simplest and most scientifically appropriate assumption, which is that the existing **4°- 5°** standing shod inversion does not somehow suddenly disappear without biomechanical explanation when the test subjects run, then its resulting known coupling effect would be an average of **7°- 8.5°** of external tibial rotation.

As an offsetting rotation, that **7°- 8.5°** of **external** tibial rotation nearly accounts for all of the missing average of **10°** of tibial **internal** rotation in Willwacher's test data that would be expected from his observed average of **11°** of peak ankle or calcaneal eversion at max bodyweight load in midstance (**18°** of tibial internal rotation would be expected in normal, static coupling, but only **8°** was observed in his running study, so **10°** of tibial **internal** rotation is missing and thus indicates decoupling in that amount).

Moreover, based on **FIGURES 6B, 7, and 8A&B**, at least some increase in supination would be expected to occur from the standing to running due to the much higher load (4 to 6 times) and substantial leg flex during running. If you just use Rubin's Ratio of 1:1.7 to fully account for the **10°** of missing tibial internal rotation, the result of my full analysis in **Endnote 11** of the published Willwacher data indicates that the elevated shoe heels of his test subjects (unmeasured, but typically 6-12mm) artificially created an average for all test subjects of about **6° of supination** during midstance when running.

That result is in basic agreement with the reported landing position of the foot while running, when the unloaded condition can be expected to reflect accurately the position of the shoe-heel induced supinated subtalar joint on the foot, as indicated by calcaneal inversion. That is, the unloaded calcaneal inversion when landing reflects the cumulative effect of the millions of repetitions of 2-3 times bodyweight load in an unnatural **6° of subtalar joint supination**.

The landing position of the foot while running has been reported in studies to be on average 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 13 separate running studies by well-known researchers (compared to an average angle of **1.5°** for modern barefoot runners in three studies) in the book he edited in 1990, ***Biomechanics of Distance Running***.

In addition, Willwacher's **4° of standing ankle inversion for males** is essentially the same as the **4° of varus** used by the distinguished podiatrist **Steven Subotnick**, who pioneered the treatment of running injuries, at that time for a majority of male patients. In 1976 Dr. Subotnick convinced the **Brooks** Shoe Company to use a **4° varus wedge** (**FIGURE 1D**), shown on left as **20°** to make the angular difference more noticeable) in what became for many years its top-rated Brooks Vantage running shoe (and still in widespread use today the form of **midsole density** variations in many "stability" or "guidance" categories of running shoes produced by many shoe companies).

As shown on the left in **FIGURE 1D**, the varus wedge puts the subtalar (or lower) 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 surface below it and the subtalar joint is thereby left in the inherently unstable position shown in **FIGURES 6B, 7, and 8A&B**, thereby subject to unnaturally excessive pronation.

However, the varus wedge maintains the heel, ankle, and lower leg in an abnormal **4° varus** position, instead of in a naturally stable vertical position, as shown previously in **FIGURES 6A&B, 7, and 8A&B**. As we will soon see, this causes major structural abnormalities in the modern human body.

Dr. Subotnick's **4° varus** wedge does indicate clearly, however, that the problem of the anomalous supination position of the modern foot during running has been recognized as a biomechanical fact for many decades. In fact, 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 James footprint study of **FIGURES 1A&B**).

Instead of using a wedge to tilt against varus effects, at least one company, **OESHshoes**, has developed in the past decade a sole technology with a load-adjusting valgus tilt. Dr. **Casey Kerrigan**, MD, developed the technology to counteract the problem she found in the numerous studies she conducted at the Running Lab she set up at Harvard Medical School in the 1990's.

The studies were published in journals like the ***Lancet*** and focused on the varus effects of increased knee joint torques caused by elevated heels, which are particularly a problem for women and their very high incidence of knee osteoarthritis. Her running shoe sole technology reduced those torques by providing a compliant valgus tilt under a bodyweight load to make the leg more vertical while walking or running. However, more recently that technology has apparently been superseded at OESHshoes by a 3D-printed flat sole with no heel elevation.

Finally, a recent medical study has noted that 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**.[10] [I]

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?

My Analysis of Dr. Willwacher's Data Provides Even More Compelling Evidence of Shoe Heel-Induced Supination

Although all of this substantial accumulation of evidence supports the biomechanical reality of the modern foot's supination, my analysis of Dr. Willwacher's data provides even more exacting support in **Endnote 11**.

Summarizing the analysis as noted above, the Willwacher data indicates that the observed running midstance eversion of the ankle joint produces **10°** less internal tibia rotation than forecast by Rubin's static coupling ratio illustrated in **FIGURE 5B**. That is the observed decoupling.

The missing internal tibia rotation of **10°** mathematically matches the amount of external tibia rotation of **10°**, which is due precisely as expected by Rubin's ratio of 1:1.7 to the **6°** of shoe heel-induced unnatural supination of the foot, which is what causes the decoupling.

The data therefore strongly supports the argument that the runner's foot typically everts, as indicated by ankle or calcaneal eversion - unnaturally and excessively – in order to compensate for the artificial supination effect of the elevated shoe heel. The elevated shoe heel artificially rotates the tibia externally into the mechanically unstable position shown in **FIGURES 8A&B**.

Whether a runner's leg ends up in a bow-legged, knock-kneed, or neutral position is idiosyncratic: a specific compensation determined by each individual's particular anatomy, whereby an unnatural biomechanical equilibrium is reached for each body, in reaction to the artificial destabilizing effect of shoe heels.

In summary, Dr. Willwacher's data indicates that the artificial elevated shoe heels of his test subjects lock their subtalar ankle joint into an abnormal supination position that averages about 6° at the midstance peak of the bodyweight load.

That unnatural supination forces unnatural foot eversion in reaction, as measured most typically by rearfoot or ankle or calcaneal eversion. The supination also simultaneously decouples the natural rotation of the tibia by artificially rotating it externally an average of about 10° at the midstance peak load of the unnatural foot eversion.

The Shoe Heel's Supination Effect Continues Throughout the Midstance Phase of Running, Even When the Foot Is in Maximum Eversion

The most obvious biomechanical effect of elevated shoe heels is a supination shift that moves the tibia and fibula that form the upper ankle joint physically backwards on the joint surface of the talus, which forms the forms the lower ankle joint, as illustrated in **FIGURE 2B.** So, if the heel lift is **10°**, then the position of the tibia is **10°** behind its natural location throughout the load-bearing midstance phase of running (after landing and before the heel naturally raises, as the foot moves into planterflexion in the propulsion phase).

This supination shift that repositions the tibia backward on the talus explains an otherwise seemingly inexplicable result: namely, that the foot can be maximally everted while at the same time still being supinated by an elevated shoe heel.

The way to understand this odd fact is that, in the example, the **10°** backward repositioning of the tibia on the talus by the shoe heel remains whatever the position of the ankle joint in dorsiflexion or plantarflexion during the stance phase of running. The ankle joint's entire range of motion has been shifted backward on the trochlear surface of the talus by the **10°** elevation of shoe heels, as shown in **FIGURE 2B**.

That is, for example, even when the ankle is maximally dorsiflexed during running, as shown in **FIGURE 7**, the tibia is still **10°** behind its natural position at the front-end of the ankle joint trochlear surface. As a result, the windlass effect of **FIGURES 4A&B** will not fully unlock the subtalar joint even in extreme pronation, as shown in **FIGURE 5A**.

In other words, whatever position the subtalar joint is in during pronation, even at maximum pronation during peak dorsiflexion running, the abnormal 10° backward position of the tibia on the talus biomechanically rotates the subtalar joint externally (due to the windlass effect and the natural structure of the subtalar joint).

That 10° backward position of the tibia puts the subtalar joint into a more supinated position (by 6°, for example) that also rotates the tibia externally (by 10°, for example), creating the decoupling effect discussed above in modern shod runners.

Conclusive Evidence of Subtalar Joint Supination During Running Provided by Dynamic Biplanar Radiographic/CT Scan 3D Modeling

All of the preceding evidence on the position of the subtalar joint has been obtained indirectly, because it has not been technically possible to observe directly the motion of the subtalar joint during motion, particularly during the loadbearing stance phase of running. Therefore, whether old or new, no previous study has provided accurate measurements of such subtalar joint motion, only inferences based on the motion of the ankle joint, as observed by calcaneus and tibia, and of the foot.[12A]

The motion during locomotion of the subtalar joint itself has been effectively invisible in all previous studies. An intracortical pin study attempted to bridge this important gap,[12B] but a subsequent evaluation indicated that accurate results were not achieved, despite the almost insurmountable difficulties that were overcome to perform it.

That evaluation was made possible through a new measurement technique that provides such a significant breakthrough in accuracy it literally makes visible what was invisible. The technique uses dynamic, biplanar radiographic images of the running foot and lower leg, combined with computed tomography (CT) scans of the distal tibia and entire foot to make CT-based 3D bone models in loadbearing motion.[12C] It is so accurate it establishes a new gold standard in accuracy, far exceeding what was previously available, and making possible for the first time ever accurate measurement of subtalar joint during locomotion, particularly running, the most difficult to measure.

Oddly enough, those extraordinarily accurate measurements of the subtalar joint during running are buried in a study that apparently did not notice an extraordinary result contained within it, since it was not commented upon by the researchers. That extraordinary result was that the subtalar joint is substantially supinated as measured in the frontal plane throughout the midstance phase of running, including at peak bodyweight load (typically almost 3 times bodyweight).

The study by Peltz et al. included a group of 12 runners (6 female, 6 male). As indicated in Figure 7 of the study, which is a chart of subtalar joint inversion/eversion from footstrike to heel-off, the touchdown angle was 11.5°-12.5° subtalar joint inversion (the calcaneus inverted relative to the talus). Most significantly, the subtalar joint pronated under peak load at midstance but remained at 5°-6° of inversion even under that peak load.[12D]

It cannot be overemphasized that this definitive finding that the subtalar joint remains substantially supinated throughout running midstance firmly contradicts the conventional biomechanical wisdom, which is that the subtalar joint is in pronation at midstance for virtually all runners. Instead, the subtalar joint is only reducing its still substantial supination. The conventional wisdom is based entirely on the misunderstood observation of calcaneal eversion alone, which is caused by the reduction of subtalar joint inversion of about 6.5°.

Perhaps even more unexpected, the subtalar joint is supinated in the transverse plane by even more throughout the stance phase of running. As indicated in the study's Figure 8 on subtalar joint external/internal rotation, the talus is externally rotated about 11° on the calcaneus at touchdown and declines by only about 3° to an external rotation of about 8° even during peak load at midstance.

Of equal importance, the Peltz study also used the same incredibly accurate technology to measure tibiotalar or ankle joint motion during the running tests. In the study's Figure 4, it provided the result that the tibia is inverted about 2°-2.5° at the ankle joint relative to the talus during midstance. Combining that ankle inversion with about 6° of subtalar joint inversion at midstance, the resulting 8° of tibial inversion provides confirmation of the overall accuracy of the 8° of tibial inversion established as a fixed baseline by Cavanagh and Frederick as an accurate approach to measuring highly variable rearfoot motion in the absence of any direct knowledge of the motion of the subtalar joint during motion.

Why the Shoe Heel-Induced Supination Has Remained Hidden for So Long

The shoe heel-induced 6° supination has remained hidden from researchers until now because the measurement of subtalar pronation has always been taken as rearfoot or ankle or calcaneal eversion in the frontal plane. Exclusive reliance on that parameter to measure the subtalar joint motion completely obscures the fact that both shoe heel-induced supination action and pronation reaction net out to a resultant, unnatural subtalar motion.

Proof of this persistent backward abnormal position of the tibia on the talus caused by shoe heels is provided by a number of old physical anthropology studies indicating that never-shod barefoot humans have **squatting facets** at the most forward portion of their ankle bone's trochlear surfaces, whereas those of modern shod humans do not, as shown in **FIGURES 10A&B**.

A proper understanding of the function of "squatting facets" in never-shod barefoot humans is that they are, in fact, primarily **running facets**. That seems abundantly clear from the position of the runner's ankle joint in **FIGURE 7**, which strongly indicates that the tibia contacts the talus of the runner when the ankle joint is at peak dorsiflexion (and, simultaneously, peak load). They thereby provide direct structural support to the tibia, increasing energy efficiency by reducing the need for muscular control.

Furthermore, in the maximum dorsiflexed position, even the modern tibia and talus of modern shod humans have matching interlocking margins that fit together exactly, despite their highly complex biological structure.

Thus, we have obvious further proof from the absence of running facets that modern shod runners have tibias that are permanently positioned substantially behind their natural position in the ankle joint surface during the entire stance phase of running (as well as other forms of locomotion and even simply standing) inherently creating an unnatural supination position of the foot.

That unnatural posterior repositioning of the tibia caused by the elevated shoe heel permanently interrupts the windlass effect and its natural synchronization with the structure of the subtalar joint shown in **FIGURES 4A&B and 5A**. It thereby permanently decouples the rotation of the tibia from the ankle joint during running.

In consequence, the tibia will always have an unnatural external rotation component (depending on the height of elevated shoe heels) that inherently alters its natural rotation due to normal coupling (depending on how far to the rear the tibia is positioned on the talus by the shoe heels). As we shall soon see, the actual anatomical structure of the modern ankle joint is altered as a result.

Further Evidence of Shoe Heel-Induced Torque That Tilts & Rotates the Knee Externally Outward

Before going further, some additional proof of the shoe heel bio-mechanism itself should be examined. Evidence reflected in the Knee Moment Frontal Plane graph of Figure 4 of the same celebrated study by Steffen **Willwacher** and others[11] indicates a powerful **external knee adduction moment (or torque).** This external torque forces the knee to tilt out into a bow-legged (called varus) position in the frontal plane.

A similar powerful **external rotation torque** occurs in the horizontal plane, as shown in the Knee Moment Transversal Plane graph of the Willwacher et al. Figure 4. This external torque forces the knee out into a twisted-out position in the horizontal plane.

As the previous discussion of **FIGURES 4A&B, 5A&B, 6A&B & 8A** indicates, both torques are at a peak at midstance when the knee is maximally flexed about **40°** and under peak body weight load.

As summarized in **FIGURE 8C**, the data that stands out as extra-ordinary is that the peak of **external knee adduction moment (or torque)** in the frontal plane extends almost all the way from about **20%** to about **60%** of the stance phase. The peak, in other words, is not really a peak, but instead **a particularly extended plateau of powerful unnatural torque** that forces the knee into an abnormal varus or bowlegged position.

The dual torques shown in **FIGURES 8C** act together to both tilt out and externally rotate the knee toward an artificial **varus or bow-legged (or adducted) position** shown in **FIGURES 8 D&E**. This corroborates the earlier discussion on decoupling and the biomechanical effect of conventional shoe heels. (Note the confusion generated because the two sets of figures use the opposite directional terminology, adduction or abduction, to describe exactly the same knee joint torque).

Other Research Studies Confirm That Runners' Knees Are Forced into a Varus (Bow-Legged) Position

An important recent study of runners by Radzak cited earlier – that avoids this confusing abduction versus adduction terminology - indicates that, there is an average of about **8° of knee varus (bow-legged, tilted-out) position** (in the frontal plane) at the maximum **40°** flexed position of the runner's knee (in the sagittal plane).[10D]

A different, earlier study by McClay indicated that normal runners have **7° of knee varus (bow-legged) position,** and even runners with excessive pronation demonstrate about **2° of varus thrust motion to the outside** through the first 25% of the stance phase.[10E]

These studies clearly confirm the unnatural knee varus-inducing effect of elevated shoe heels. Summarizing those results and my analysis of Willwacher's study, during running **an average of 6° of foot supination produces an average of 7°-8° of knee varus.**

Additional Research Studies Have Also Confirmed the Twisting Effect of Elevated Shoe Heels on Ankle Joint and Foot

In summary, the elevated shoe heel is an artificial structure that activates a bio-mechanism in the subtalar ankle joint that twists each foot to the outside into a supination position. The simple twisting mechanism is an automatic and unnatural external rotation.

Since 2002, four different peer-reviewed biomechanical studies[13] have confirmed this basic mechanical relationship between elevated shoe heel and tilting-out supination (in addition to the Willwacher study and other studies cited above).

The Confused Existing State of Footwear Science and the Biomechanics of Running

From the previous data, we have observed the shoe heel has an enormous effect during running on the biomechanics of the foot and lower leg, including the ankle joint and knee joint. By far, that abnormal effect is the largest single factor altering the known static joint mechanisms by decoupling them, and yet – extraordinarily – the shoe heel effect has remained unknown and unaccounted in the existing research studies on running biomechanics cited above (except the four cited in Endnote 13), and likewise omitted in all other research studies.

This unintentional but critical omission has functioned, in effect, as a **key** that inadvertently encrypts the empirical results of these running studies, making those results at worst an undecipherable jumble of unrelated numbers with no observable underlying connection. As a direct result, the decoupling effect has remained a mystery for decades.

Only by using the **key** – knowledge of the artificial factor of the biomechanical effect of elevated shoe heels - to add onto the well-known static relationship between subtalar joint and tibia can the empirical data of running studies be unlocked into coherent results upon which valid biomechanical and anatomical sciences can be built.

But that is only the first step. This confused current state of affairs, however, is exacerbated by yet another, additional factor that the existing research studies have also ignored unintentionally.

During a lifetime, the biomechanical effect of shoe heels artificially changes the actual physical structure of modern human bones and the joints connecting them. Until now, we have assumed that those structures are anatomically natural, but they are in fact pathologically abnormal.

In summary, the bio-mechanism of the elevated shoe heel acting on the subtalar joint described above and shown in **FIGURES 1-8** creates a simple, if seemingly unlikely, physical reality (however well-hidden until now). The available peer-reviewed research corroborates its accuracy.

If the reality of the elevated shoe heel bio-mechanism is unavoidably acknowledged, then it is probable that the unnatural bio-mechanism would have direct structural and functional effects on the human body during running. Because maximal forces are involved then - repetitive loads of two-to-three times body weight – the effect are likely to be major.

Seemingly innocuous shoe heels actually have had an enormously consequential power to shape our bodies. **Starting with the knee in FIGURE 9, the modern human body provides a trail of direct physical evidence of that power of elevated shoe heels to have deformed it.**

The Abnormal Disequilibrium of the Tilted-Out Lower Leg Distorts the Natural Shape of the Modern Knee and Ankle

When natural human leg is in its natural position - vertically aligned - the body weight load on it is also vertical. As a result, the leg bones are subjected to a vertical **compressive force** for which their structure and material composition are optimized.

However, when the modern human leg is tilted-out unnaturally by an elevated shoe heel, the compressive force is reduced, and a new and **unnatural shear force** – the horizontal component vector in **FIGURES 8A&B** – is introduced. The shear force cannot be supported adequately by bone alone.

To resist destabilization, the abnormal shear force also must be resisted by the soft supporting tissue of the ankle and knee joints, including muscle, tendon, and ligament. Unfortunately, those soft tissues are subject to fatigue and stretching out of normal position, resulting over time in an unnatural distortion of the joint. That pathological distortion allows the bones of the joint to become misaligned and therefore less robust and functionally effective.

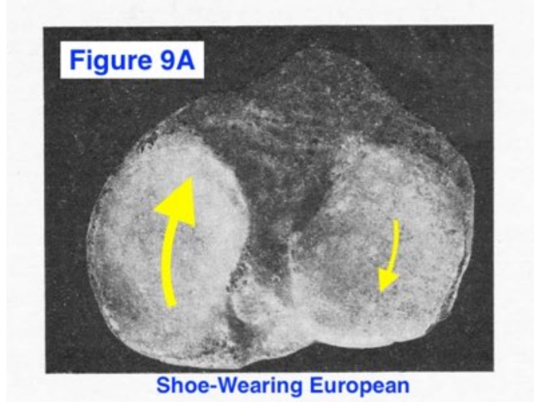
The overall distortion is an abnormal joint enlargement that includes an actual remodeling of the bones of the joints. That remodeling includes a rotary torsion is built into the bone structure of the knee and ankle in reaction to the unnatural external rotation of the lower leg by the elevated shoe heel.

The Modern Knee is Restructured by the Unnatural Rotary Torsion of Running with Elevated Shoe Heels

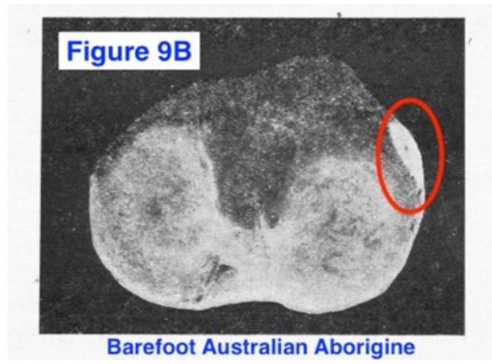
The key biomechanical reality controlling modern knee motion during running is that <u>6°</u> of artificial supination of the foot is coupled to about <u>10°</u> of unnatural external rotation of the tibia, based on my analysis of Dr. Willwacher's published data. That result is supported by Dr. Willwacher's unpublished data that just standing in running shoes alone creates an average of <u>5° (male) to 6° (female) of external rotation of the tibia</u>, which is directly coupled to the 4° to 5° of standing foot supination noted earlier.

The abnormally tilted out position of the lower leg on the knee joint shown in **FIGURES 6B & 8A** creates unnatural increased pressure on the inside or medial portion of the knee and simultaneously reduced pressure on the knee's outside or lateral portion.

That abnormal, extreme stress causes an unnatural and pathological restructuring of the knee while tilted out. The tilting creates an unnatural rotary motion. It unbalances the load on the knee by massively over-loading the medial (inside) portion. The unnatural rotary torque becomes built into the shape and structure of the modern knee joint. The result over time is that nearly all runners become <u>former</u> runners due to knee pain, and of those, many become non-walkers due to knee arthritis caused by their deformed knees. Also resulting are otherwise avoidable acute injuries to the ACL and other knee ligaments, and knee cartilage (or menisci).



Shoe-Wearing European



Barefoot Australian Aborigine

As **FIGURE 9A** demonstrates, in the top photograph, the modern European (right) knee (tibial plateau) has an abnormal rotary motion (in the horizontal plane) molded into the bone structure of either or both knees. The barefoot (right) knee of an Australian aborigine, as **FIGURE 9B** shows in the bottom photograph, is natural and therefore shows no evidence of abnormal rotary motion. In addition, both tibias are the same length, indicating that the modern knee joint is unnaturally enlarged compared to the natural knee joint.

In **FIGURE 9C,** similar tibia samples from barefoot populations in India show the same simple, non-rotary structure as the Australian. This is true despite Indians being a distinctly different genetic line from an entirely different major genus homo migration out of Africa. In fact, Indians are considered Caucasian, genetically identical to Western Europeans[14].

The forgoing differences between modern and barefoot knees strongly suggests that the rotary motion of the screw home mechanism of the modern knee is an artificial and abnormal feature caused by elevated shoe heels. The available evidence suggests that it is not a genetic difference at all.

In addition, an ancient Roman sample shown in **FIGURE 9D** also shows the same simple, non-rotary structure as the barefoot Australian and Indians. While it is likely native Italian, its exact genetic lineage is not currently known and therefore could theoretically have come potentially from anywhere in the genetically diverse Roman Empire[14].

Moreover, if you look at the lower surface of the modern (right) knee joint (the tibial plateau) in **FIGURE 9E,** you can see obvious menisci cartilage (highlighted in yellow) on top of the bone surface showing evidence of exactly the horizontal rotary motion of the horizontal rotary action occurring as described above. The medial side meniscus cartilage (on the left side) is obviously pushed forward completely out of a centered position, with its foremost section seriously eroded, unlike the rearward-centered position of the lateral meniscus.

In contrast, **FIGURE 9F** shows a drawing of a barefoot tibial plateau and, separately to the right, the twin right and left menisci, which are highly symmetical mirror images of each other.

As we shall see, the right and left knee joints of any given modern individual may have the very different amounts of unnatural rotary motion built into the structure of their tibial plateaus, due to an exaggerated right/left asymmetry in the individual body – artificially caused by shoe heels.

Figure 9E
Modern Knee Joint

The Unnatural Rotary Milling Mechanism of the Modern Knee Joint

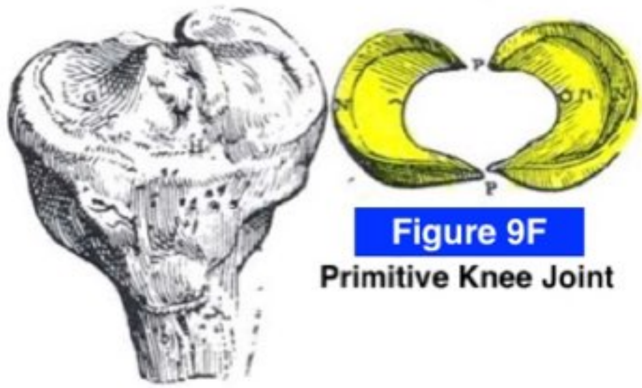
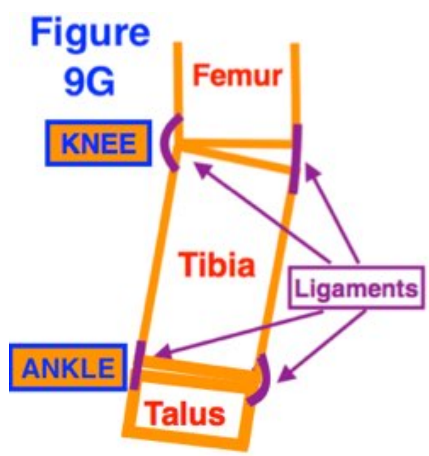


Figure 9F
Primitive Knee Joint

When running with elevated shoe heels that both rotate and tilt our shinbones to the outside under a maximal 3 times body weight peak vertical load with knee flexed at roughly 35°, the following unnatural knee joint mechanisms must occur biomechanically, as viewed in the horizontal or transverse plane: **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.**



Talus Tilts Out Right Leg

First, the initial tilting to the outside of the tibia by the shoe heel-tilted modern talus causes the **medial** (inside) surfaces of a right knee, for example, to be pressed very tightly together. Therefore, **the medial collateral ligament of the right knee becomes very loose,** as shown in a frontal plane view schematically on the left side in **FIGURE 9G**, **allowing the medial (inside) condyle of the thigh (femur) bone to slide forward on the medial tibial plateau**; that is, the femur rotates externally to the tibia.

Second, in contrast to the medial side surfaces, the right knee's **lateral** (outside) surfaces are pulled apart by the outward tilting of the tibia, as shown schematically on the right side of **FIGURE 9G**. Therefore, the lateral collateral ligament becomes very tight and anchors lateral condyle on the lateral tibial plateau, locating the **center of rotation** there, in a slightly posterior location. The lack of motion of the lateral condyle allows the lateral meniscus to remain firmly in its natural position and also remain relatively intact.

A horizontal cross-section in **FIGURE 9H** showing the internal bone trabecular structure of the (right) modern knee shows the clear evidence in the denser trabecular structure (highlighted in yellow) of the fixed lateral side and the mobile, elongated medial side (with a much denser network of trabecular bone on the medial portion of the knee).

Third, furthermore, the outwarded tilted and rotated shinbone pulls with a powerful vertical force 2 to 3 times body weight through the patellar tendon through the **patella (knee cap)** on the thigh bone (femur) in an unnaturally oblique direction between the two bones in this misaligned position (ie. with the tibia rotated to the inside relative to the femur).

The tibia's outward tilting puts the medial portion of the knee joint under disproportionately great pressure during this abnormal forward sliding motion (60% typically and as high as 80% of the knee's load), as seen in much denser (highlighted) trabeculae on the medial side of **FIGURE 9I**, an anterior coronal section of the tibia. The forward motion of the relatively loose medial femoral condyle forces the medial meniscus forward and substantially erodes the forward (anterior) portion of the medial meniscus over time.

The Modern Knee's Mysterious Screw-Home Mechanism: the never before explained function of the screw-home mechanism is to return the knee to a natural, non-rotated position as it transitions from a roughly 15° flexed position to an extended, straight-legged position. The abnormal rotation shown in **FIGURE 9H** is simply reversed, with the medial condyle of the femur moving backwards on the tibial plateau, back to its natural position. This rotary milling process – literally a grinding motion – is the unnatural cause of osteoarthritis of the modern knee, the most common form of arthritis.

Data from the Willwacher study (graph on **Knee Angles in Transversal Plane** – in Endnote **11**) provides clear evidence of this abnormal rotary motion in the modern knee. During the stance phase of running, the graph shows an internal and external rotation range of horizontal motion of the knee of about **8°**. The graph also shows a total rotational distance of back and forth motion of about **20°** in the transverse (or horizontal) plane with every full running stride.[15]

Think of this abnormal rotational movement in terms of a grinding motion, like mill stones grinding wheat, except that it is the unnaturally shaped inner surfaces of your knee that are grinding against each other, displacing and destroying knee cartilage, as well as stretching knee ligaments out of their normal operating positions. The logical conclusion is this unnatural rotary grinding action almost certainly accelerates or causes knee osteoarthritis, the most common modern form of arthritis (for which no cause has been otherwise identified).

Like the Knee, the Modern Ankle Is Restructured by Unnatural Rotary Torsion

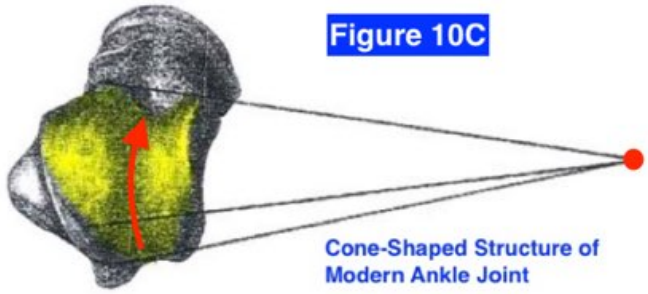
Like the modern rotary knee joint, the modern (left) ankle bone shown in **FIGURE 10B** shows the same rotary motion induced enlargement, especially when compared to a natural barefoot Egyptian (left) ankle bone shown in **FIGURE 10A**.

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

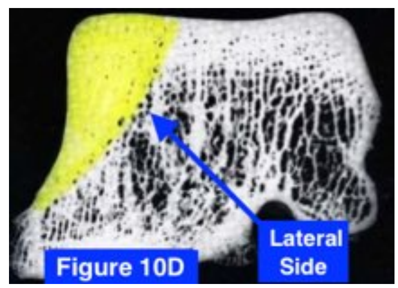
FIGURE 10C shows more definitively the well-known but unnatural rotary structure built into the modern (left) ankle joint (ankle joint trochlear surfaces highlighted in yellow).

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.

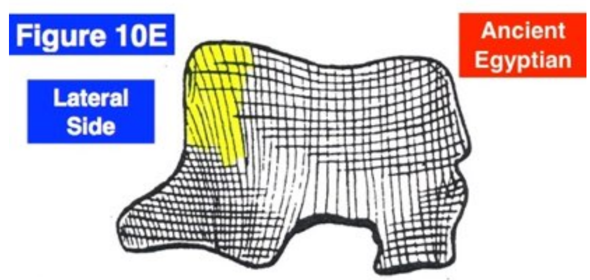
However, in this case, based on the governing simple geometry, **the joint sides <u>reverse</u> their roles, with the lateral side on the modern ankle joint becoming looser and the medial side becoming more fixed, as shown in a frontal plane schematically in FIGURE 9G, resulting in the rotary joint structure shown in FIGURE 10C.**



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.

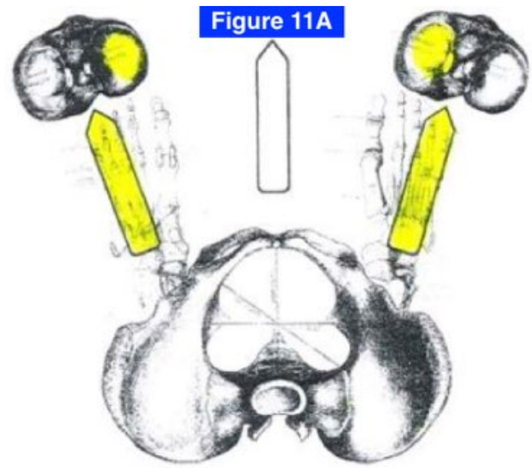


Showing the arrangement of the lamellæ in a trans-section through the corpus.

Both Modern Ankle Joints Point Unnaturally to the Outside, Not Straight Ahead

The higher the artificial heel, the greater the outward twisted position of the supinated feet. In particular during childhood but throughout life, that simple twisting mechanism gradually changes the shape and function of every part of the human body, including the knee.

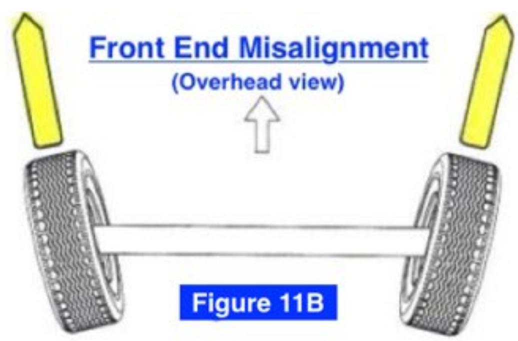
As illustrated in **FIGURE 11A**, the ankle joint of the modern right foot is twisted outward to the right, and the ankle joint of the modern left foot is twisted outward to the left. Both are twisted outward instead of pointed straight ahead, as would be natural. As a result, both knees are also unnaturally forced to the outside unnaturally, and most of the body weight load becomes abnormally shifted to the inside (medial) half of the knee (in yellow).



Your Modern Body Has a Major Front-End Misalignment That Causes Unnatural Breakdowns and Accidents

Imagine for a minute this crude car analogy, where your legs and pelvis are the front end of the car. Your legs are the wheels and suspension, and your pelvis is the rest of the front end of a car. Because of elevated shoe heels, your front end is, to put it mildly, not correctly aligned. Instead, your front end has become splayed out abnormally.

In effect, each wheel has over-inflated tires. In this they resemble your unnaturally rigid, abnormally supinated foot. Your supinated foot – which is tilted to the outside - wears on the outside edge of the tire. In addition, each wheel is pointed in a different direction to the outside, not pointed straight ahead. The overhead view in **FIGURE 11B** illustrates this problem.



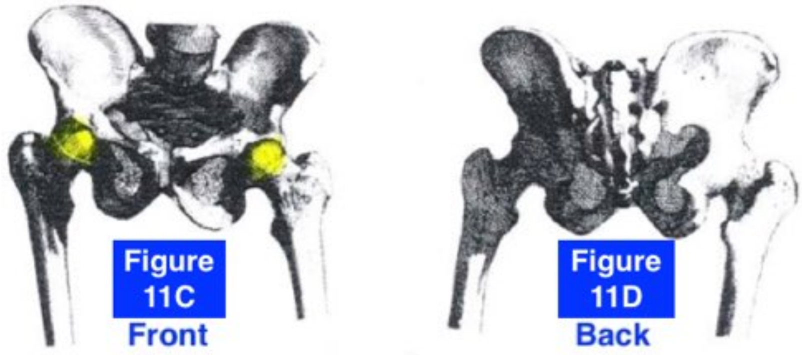
The result is easy to forecast. Your car's wheels, suspension, and front end will wear out quickly, unless they cause an accident first. Breakdown or accident, inexorably those are the only two possible outcomes of the wheel misalignment. The car will breakdown long before it ever approaches its warranty mileage.

Compared to a car, your body is a far superior and much more accommodating biological machine. The end result, however, is the same, even if the cause and effect relationship is far less obvious. The human body simply endures a slower, subtler breakdown over a much longer period of time.

Elevated shoe heels, in short, create abnormal body structures that cannot work together naturally as a complex, interrelated biomechanical system. The heels can only cause an early, unnatural breakdown.

Shoe heels also force the thigh bones to rotate unnaturally to the outside, excessively exposing the femoral heads to abnormal wear in the hip joints, as shown in the front view of **FIGURE 11C**. Conversely, in the rear view of **FIGURE 11D**, the femoral heads are completely covered and located abnormally deep within the hip sockets.

At this point I should note that the actual structural orientation of the natural, un-deformed hip joint is not optimized for standing fully upright and walking (as typically shown above). Instead, the hip joint orientation is optimized for running in a flexed position, like the knee, because that is when it is maximally loaded at 2-3 times body weight), as shown previously in **FIGURE 7**.



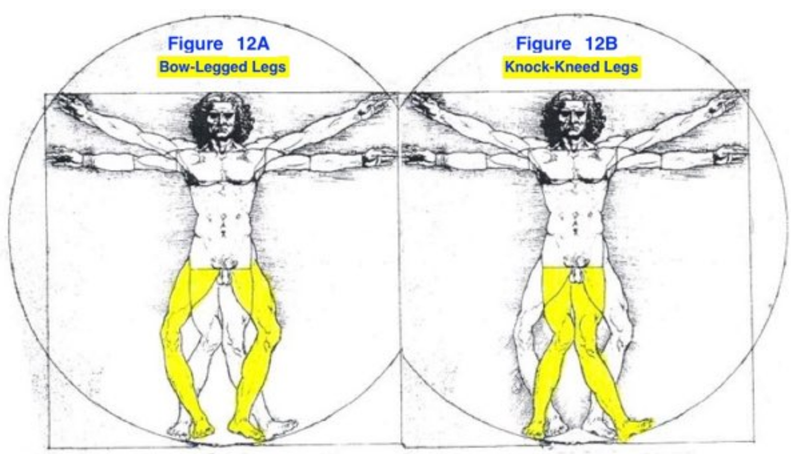
Until now, the scientific consensus incorrectly has been that exposed position of the hip joint resulted from incomplete human evolution to bipedal locomotion from its quadrupedal antecedent. In other words, the evolution from quadrupedal flexed legs to bipedal upright and vertical, with straight legs, has been assumed to be simply unfinished.

Evolution, however, has not optimized the human body for standing or walking upright with straight, vertical legs. Evolution, instead, has optimized the human body for running, with flexed hip and flexed knee (at two-to-three times body weight load) at roughly **45º** leg flex, a degree which coincides with the max load running position shown in **FIGURE 7**.

The Basic Alignment of Modern Human Legs Is Altered by Shoe Heels

Structural instability inherently directly affects everyone who typically wears shoe heels, but each individual adapts in their own particular way. Many factors are in play, including unlucky injuries, but generally those individuals with stiffer subtalar joint and foot arches maintain the supinated foot position, which causes their legs to bend outward into a **bow-legged** position. See **FIGURE 12A** below.

The feet of individuals who have more flexible subtalar joint and foot arches are forced to rotate inward in pronation in reaction to the unnatural horizontal component vector acting on the subtalar joint. That abnormally excessive pronation causes their legs to bend inward into **knock-kneed** positions. See **FIGURE 12B**.



Both positions - bow-legged and knock-kneed - are opposites, yet both result directly from the same unnatural effect: the inherently unstable position caused by shoe heels, as **FIGURES 8 C&D** illustrated previously.

The inherent instability of shoe heels, in short, forcibly creates an unnaturally wide spectrum of adaptations by individual to compensate for the unbalanced equilibrium. A lucky few are precariously balanced in the middle, neutral position with vertically aligned legs, but the rest are not, and many have greatly exaggerated misalignment.

Male Tendencies: This unnatural imbalance exaggerates the disparity between modern male and female bodies. They are artificially made abnormally different. Most modern **men tend to become bow-legged**, as shown above in **FIGURE 12A**, often with a noticeable knee bending motion to the outside when flexed during locomotion. This abnormal condition, called varus knee thrust, weakens their legs and reduces their ability to jump. Modern **male feet tend to become fixed in the supination position** in reaction to elevated shoe heels.

Female Tendencies: Modern women also experience this unnatural twisting mechanism, but in contrast, most **women tend to become the opposite, knock-kneed**, as shown in **FIGURE 12B**. Women primarily experience this opposite effect because of their frequent use of much higher heels, their wider pelvis (due to relatively shorter thigh bones), and their greater joint flexibility – all of which cause their legs to rotate inward. Although they also tend to supinate initially, modern **female feet are then generally forced into excessive pronation**, in reaction to the greater imbalance of forces generated by higher elevated shoe heels.

This major structure difference between human males and females (and others that are related and will soon be discussed) probably explain what would otherwise be a very odd fact: the differences in personality traits between men and women are larger in modern cultures.[15A]

This is despite that fact that women in those modern cultures have more opportunities equal to men, which would seem to suggest that such women would therefore have personality traits more like men, not more different. In spite of this logical expectation, it is likely that the personalities of men and women are more different because of the unnaturally different structure of their bodies, which have been abnormally deformed by elevated shoe heels. The natural bodies of men and women are likely much more alike in all respects, other than the structure and function of their naturally differentiated sexual organs.

The Illiotibial Tract Plays a Crucial Structural Role in Rotating the Modern Pelvis Backwards and Forwards in Mechanical Reaction to Unnatural Foot Supination and Pronation

As **FIGURE 13A** shows, the illiotibial tract is a long ligament connecting the pelvic crest to the upper, outside edge of the tibia. **When the foot supinates, the iliotibial tract forces the pelvis to rotate backwards (in the sagittal plane) when the tibia rotates outward in reaction to the**

foot supination, including the supination caused by elevated shoe heels (as shown previously in **FIGURE 6 B**). This is characteristic of modern males.

Conversely, when the foot pronates, the illiotibial tract forces the pelvis to rotate forward (in the sagittal plane) when the tibia rotates inward in reaction to the foot pronation forced by the unnatural horizontal force vector caused by shoe heel-tilted lower leg (again, as shown in **FIGURES 8 C&D**). This is more characteristic of modern females.

Also of profound potential importance in the superior stability of the natural barefoot knee shown in **FIGURE 9B**, note carefully the bright white spot (surrounded by **red** oval) on the lower, left side of tibial plateau of the knee. That large and distinct spot marks the attachment of the illiotibial tract to the forward outside portion of the tibia of the barefoot Australian Aborigine. In the knee of the shoe-wearing European shown in **FIGURE 9A**, the equivalent attachment point is so poorly marked that it is difficult to see at all.

This evidence of major attachment difference strongly suggests that the illiotibial tract plays a critical role in stabilization of the barefoot natural knee, as well as the natural leg and pelvis. That role must be substantially reduced in the modern knee, leg, and pelvis, thereby at a minimum overstressing the other knee ligaments, showing the effect of soft tissue remodeling in accordance with Davis's Law, the corollary of Wolff's Law governing bone remodeling.

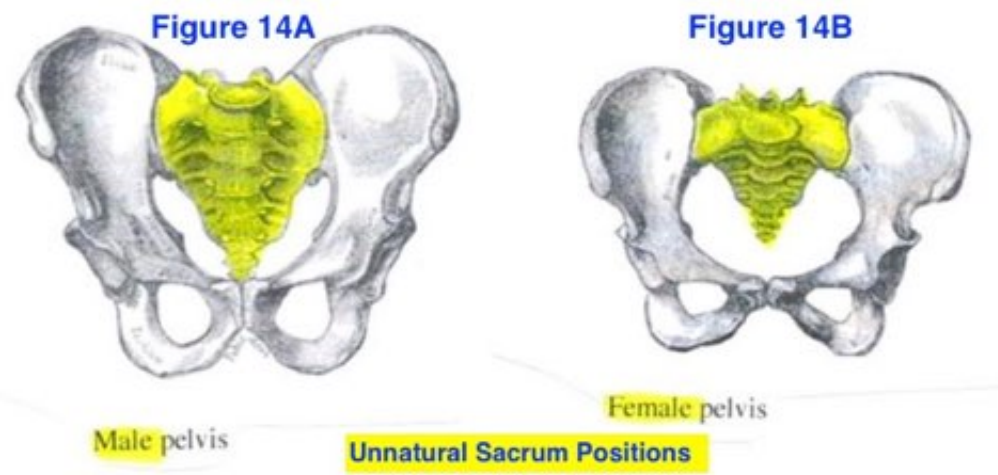
The Natural Pelvic Differences Between Male and Female Are Unnaturally Exaggerated by Shoe Heels Due to the Illiotibial Tract Mechanism

The modern **male pelvis** is typically flattened and automatically **rotated backward**, as shown in **FIGURE 13B**, because of its mechanical connection to the outward twisted knee by the critical illiotibial tract. That rotation flattens the male lower back and male butt, and softens the belly, as well as abnormally increasing the thoracic and cervical spinal curves.

The modern **female pelvis** is also typically first flattened in the same way, but then the female pelvis **rotated forward** in additional compensation, as shown above in **FIGURE 13C**. This rotation results in an excessive rounding of the female lower back and butt, as well as thoracic and cervical spinal curves, and makes pregnancy and childbirth unnaturally difficult.

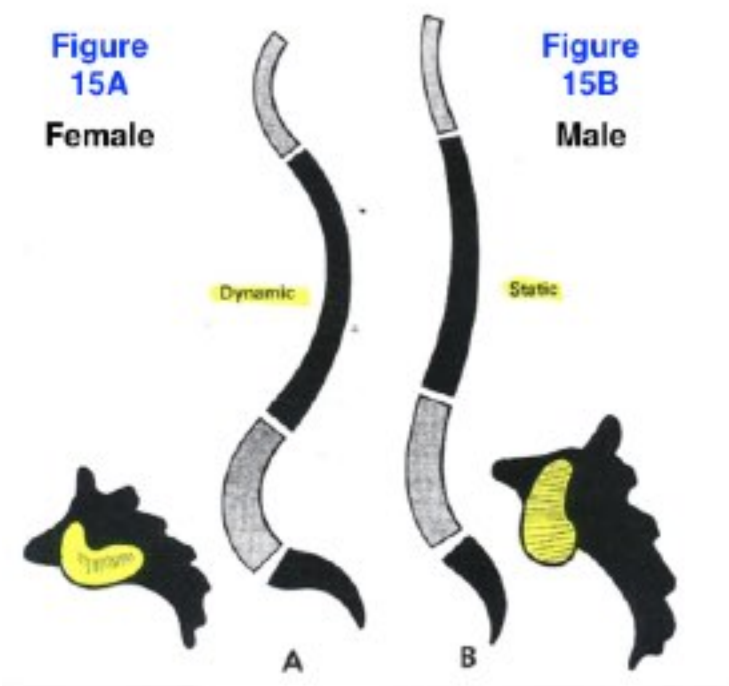
The Base of the Modern Spine Is Rotated Out of Natural Position in Both Male and Female Pelvis

In **FIGURES 14 A&B**, the sacrum (in yellow) supports and positions the spine and therefore all parts of the body above the pelvis. The sacrum is rotated abnormally backwards in the modern male figure (on left in **FIGURE 13B**) and abnormally forward in the modern female (on right in **FIGURE 13C**). The sacrum of each gender is in a different and unnatural position to provide direct support the spine above it.



The unnaturally different supporting positions of the sacrum force the curvature of the spine typically to decrease in modern **men**, shown in **FIGURE 15 B**, and make the abnormal modern male spine inherently less flexible.

In modern **women**, in contrast, the abnormal curvature of the spine is typically increased, as shown in **FIGURE 15 A**, and make it structurally more flexible. Note the drastically different sacroiliac joints (in yellow), which join the sacrum to the ilium of the pelvis. The sacroiliac joints are infamous as sites of intractable (and unnatural) pain.



In addition, the unnatural asymmetrical mismatch in pelvic position and abnormal pelvic functional ability reduce sexual performance, satisfaction, and fertility for both modern males and females. **FIGURE 15C** illustrates an extreme example of the effect of pelvic asymmetry on modern male genitalia.

Equivalent female asymmetries exist as well, although in an inherently subtler way, and of course the female breasts are often less than perfectly matched.

Figure 16A

Childbirth Is Made Dangerous by the Warped Shape of the Birth Canal in the Modern Female Pelvis

In human childbirth, the primary cause of maternal distress is the size and shape of the **baby's head** relative to the mother's pelvic opening. The head is huge, twice the size of our closest animal relative, the chimpanzee. The head on the skeleton of a newborn is so large that it makes the skeleton look as if it must belong to a space alien with an enormous brain (although at least not in the shape of the popular "cone heads" of 1990's Saturday Night Live). See **FIGURE 16A**.

The **female pelvic brim** and the fetus's relatively huge skull are about the same size (see **FIGURE 16B**). In humans, therefore, the fit is much tighter than in other primates. Mother and fetus are also mismatched in shape. The fetus must enter the birth canal sideways, and then make a difficult 90° turn, all because of the **unnaturally flattened, misshapen brim and pelvis** of the mother (see **FIGURE 16C**).

The head of the fetus has somewhat flexible sutures within the bone of the skull that help the fetus squeeze through the birth canal, as seen in **FIGURE 16D**. That inherently difficult birth passage, however, exposes the fetus's brain to enormous trauma. The fetus brain is subjected to real danger with potentially permanent consequences.

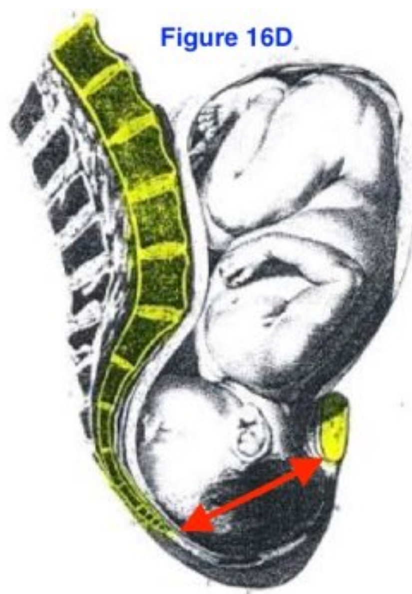
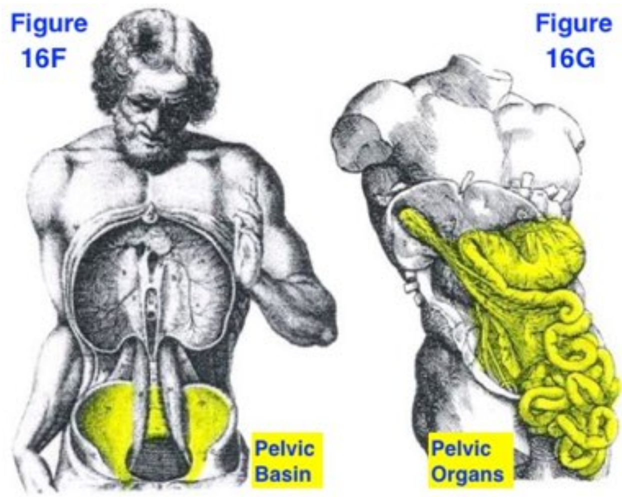


Figure 16D

The unnatural asymmetry of the mother's body, moreover, can affect the fetus's placement in the womb during its nine-month development period, as shown in **FIGURE 16E**. The most typical position of the fetus within the womb is unnaturally asymmetrical, for example, abnormally affecting its development, both before and after birth.

The word "pelvis" is Latin for basin, as shown in **FIGURE 16F**. In the human body, that basin is piled high with our internal organs, as seen in **FIGURE 16G**.

When humans tilt that basin into an abnormal backwards or forwards orientation, it would logically shift our intestines and bladder out of their natural positions, slowing down or even temporarily blocking passage of their contents. Heartburn, indigestion, gas, constipation, diarrhea, hemorrhoids, and incontinence are likely direct effects of the abnormal position of the digestive system. Sexual organs are similarly displaced and thereby subject to unnatural dysfunction.



This unnatural pelvic tilt is likely to affect adversely all of the other internal systems either contained by and/or supported by the pelvis. The other major and minor organs have a multitude of interconnections and interactions that are amazingly complicated and often quite delicate. The function of the interdependent systems of these organs is likely to be degraded in approximate proportion to the degree of abnormal pelvic tilting.

During Running, Both Legs Are Tilted In, Unnaturally Crossing Over Each Other

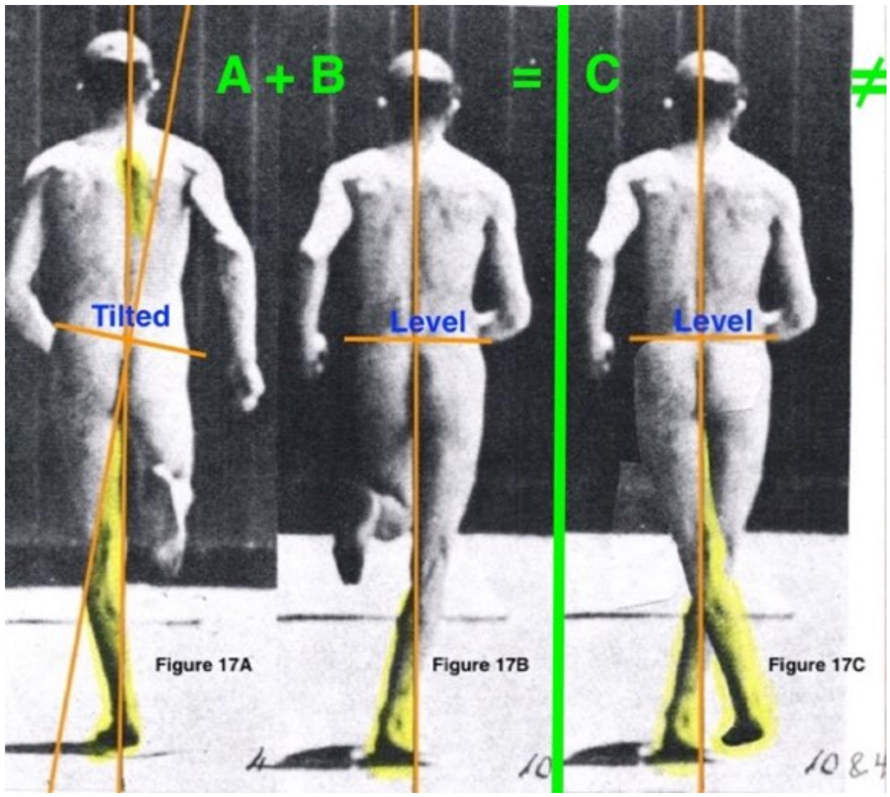
A serious alignment problem caused by shoe heels results in the modern pelvises of both sexes tending both to tilt down abnormally on one or both sides (in the frontal plane), and to twist into an asymmetrical position (in the horizontal plane).

Above the tilted pelvis, the modern spine and chest also become unnaturally twisted and bowed out, pressuring the heart and arteries (as seen in **FIGURE 17A**, the abnormal bulging right shoulder blade, compared to **FIGURE 17B**), and thereby increasing the risk or severity of cardiovascular disease.

The Typical but Bizarre Modern Crossed-Leg Position (C) Relative to the Hip Joints at the Critical Maximum Flex and Load During Running

Both views **FIGURES 17A & 17B** above shown at midstance, the pelvis tilted down on left leg, but about level on right leg. The most typical but bizarre biomechanical result is that the right leg crosses over more (about **10° inward**) than the left leg relative to the body's center. **But relative to the tilted pelvis, the left leg is actually tilted inward much more** (about **20° inward**, which is twice as much as the right leg). This is extraordinary!

Willwacher Study Data Confirms Abnormally Tilted-In Modern Legs at Midstance



The award-winning Willwacher et al. study[11] generally confirms the above results, although the study provides data only on the right leg. The study shows the right leg inward tilt (hip adduction) as about **15°** for both sexes, as shown in Hip Angle Frontal Plane graph of Figure 6.[16]

In stark contrast, a barefoot African Bushman is shown in the midstance position of running in **FIGURE 17D** with <u>no</u> leg crossover. His legs remain vertical and his pelvis is level and un-tilted. Also note his straight, well-defined spine.

Both Modern Legs Together Form an Immobilizing X-shape Relative to the Modern Pelvis at Midstance in Running

If you artificially level the modern pelvis for the left leg at midstance (taken from **FIGURES 17A & 17B** and superimposed in **FIGURE 17C**), you can begin to see the absurdity of the abnormal structural running position of the modern human body. Remember, this midstance running position is the maximal load-bearing position. The runner experiences body weight loads of two to three times, the greatest repetitive bone-forming loads to which the human body is routinely subjected during the formative growth phases pf childhood and adolescence.

This is astonishing! At midstance, the modern runner's legs are maximally loaded when their legs each form sequentially a bizarre X-shaped, crossed leg position relative to the leveled pelvis.

As **FIGURES 17 A&B** demonstrate, the **unnatural mechanical <u>tilting out</u> effect of shoe heels on both legs at the ankles paradoxically causes both legs to <u>tilt inward</u> instead at the hip joints. This result at the pelvis called hip adduction**.

That contradictory result occurs because of both legs' fixed connection to the pelvis, within which is located the body's center of gravity, which firmly resists side-to-side motion. The body's lack of relative lateral mobility - dictated by the Newton's law of inertia - forces both legs inward from the hips. And, of course, the feet are not fixed to the ground, so they can be tilted inward in compensation.

Otherwise, the massive torso would be forced to gyrate wildly from side to side with each step, in reaction to legs tilted-out by shoe heels. Nevertheless, some unnatural lateral motion is caused by shoe heels and results in inefficient motion compared to the natural stability of barefoot running.

An Even More Bizarre Change in Modern Leg Supporting Position from Standing to Running

Again, from unpublished data kindly provided by Dr. Willwacher from his earlier cited study,[11] the standing or static hip angle for 129 males is **3° of ab**duction or tilting-**out** of the leg, not adduction (tilting-in), and **2° of ab**duction or tilting-**out** for 93 females.

However, at the beginning of the stance phase in running, the starting hip angle for the **males** immediately becomes **8° of ad**duction (tilting-**in**), not abduction. This is an **amazing** change, the total hip angle increasing by a full **11° of in**ward tilt, a dramatic difference in the transition from standing to running on the male support leg.

The hip angle for **women** is **10° of tilting-in ad**duction of the leg, again starting immediately at the beginning of the running stance phase, and an equally extraordinary change, the total angle increasing by a full **12° in**ward tilt from standing to running on the female 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, making the total hip angle adduction or tilting-in change from standing to peak load running **19°** for females and **17°** for males.

In utter contrast, **FIGURE 17E** shows Kenenisa Bekele of Ethiopia as he finishes the second fastest marathon in history (2 hours, 3 minutes, 3 seconds). Bekele's legs are vertical with no crossover. His stance demonstrates the biomechanical racing advantage of a childhood and adolescence in which running barefoot was the norm (the primary reason for the almost total dominance of distance racing by Africans, especially from Kenya and Ethiopia).

Modern hip motion in the transverse plane shows the same kind of amazing change. The standing or static is **5°** for females of internal rotation and **3°** for males. At the beginning of the stance phase in running, both females and males start in external rotation and both peak at about **6°** of external rotation at maximal load midstance.

For females that is a total change from standing to peak load running of **11°** of hip external rotation and for males **9°** of hip external rotation.

Modern Pelvic Tilt Is the Only Solution to the Immobility Problem Caused by Severe Leg Crossover (Due to Tilted-In Hips and Legs)

The bizarre X-shaped legs situation shown in the **FIGURE 17C** photograph directly above is summarized in the drawings of **FIGURES 18A&B**. The mechanical action of shoe heels tilts inward both legs so acutely that they actually cross over each other (as shown in line drawing of **FIGURE 18A** on the **left**). For the human body to move forward without tripping over its own legs, at least one side of the pelvis must tilt down, so the feet no longer cross over (as shown in line drawing of **FIGURE 18A** on the **right**). The functionally short leg is loadbearing and the longer leg is non-loadbearing. This abnormal pelvic tilting enables forward motion and makes the legs more vertical.

In the **FIGURES 17 A&B** photographs, the running male demonstrates this typical pelvic compensation. To move forward, the runner's left pelvis tilts down, and this pelvic tilt effectively reduces the inward tilt of his left leg. The runner's right leg tilts in more and crosses over, under his center of gravity, while his pelvis remains level. This runner illustrates the most common male resolution to the major structural misalignment.

With High Heels, Both Sides of the Modern Female Pelvis Must Alternately Tilt Far Down During Locomotion

Compared to modern men, the unnatural structural misalignment of legs is more extreme for the typical modern woman. As a result, women typically require a greater leg realignment during locomotion than men. Females most commonly resolve their misalignment problem by tilting their pelvis down on each side, alternately with each leg when walking or running (shown walking in **FIGURE 18B**). They are forced to do so automatically due to their frequent use of higher heels (often much higher), as well as their wider pelvises, shorter femurs, and more flexible joints.

As you can see, the typical inward pelvic tilt caused by the high heels worn is very substantial, even at the much-reduced knee flexion angles and body weight loads that occur during walking (compared to running). Modern female crossover is typically much greater than modern male crossover.

Because of severe pelvic tilting, however, modern female legs often project an illusion: female legs typically appear to be almost vertical relative to the ground and positioned almost directly under the body's center of gravity (located roughly at the small of the back). Nevertheless, that is just an illusion created by the severe pelvic tilting, which causes their legs to be severely tilted-in at the hip joint.

This illusion suggests the obvious conclusion for the enduring popularity of high heel shoes with both women and men. The heels automatically require massive female pelvic tilting gyrations in order for women to simply move forward when walking.

FIGURE 18C shows a barefoot Asian child ("Napalm Girl" Kim Phuc). She has a well aligned body, with no leg tilt or crossover, or pelvic tilt, or spinal tilt when running straight ahead.

The pelvis of the same barefoot Asian girl is tilted only as required for her to change direction (in **FIGURE 18D**), with no leg tilt or crossover, or spinal tilt relative to her naturally tilted pelvis.

In contrast, the pelvis of a modern Caucasian woman (in **FIGURE 18E**) is unnaturally tilted even when running straight ahead. She demonstrates substantial leg tilt and crossover, and spinal tilt relative to her tilted pelvis, like the modern man in **FIGURE 17A**.

The Force Behind This Abnormal Pelvic Tilting Is Overpowering

At this point, I am going to bring the focus back to running, because I need to emphasize an important point. Based on frontal plane data from Figure 4 of the Wallwacher study, the peak hip torque (or moment) at midstance is about 2 Nm/kg. This peak hip torque is about 8 times greater than the peak ankle torque of about 0.25 and about 3 times greater than the peak knee torque of about 0.65. This means is that there is a much greater relative force is causing hip adduction than knee adduction and far greater force than that causing ankle eversion.

This overpowering torque, moreover, is actually forcing the pelvis to tilt downward, not the hip joint to tilt inward in adduction (nor the thigh bone to tilt inward). (Of course, in either case, the hip joint action brings the pelvis and thigh bone together relative to each other in exactly the same way.)

If the pelvis tilts downward, however, as shown on **right** in the line drawing of **FIGURE 18A** above, then the support leg – maximally flexed and loaded at midstance – can become less crossed and more vertical (relative to the ground), instead of more tilted, as shown on the **left** of the **FIGURE 18A**. (Of course, during running or walking, the low leg on the tilted down side of the pelvis is flexed upward and unloaded; the low leg is not ground contacting, it is airborne and thereby tucked out of the way.)

The inertia of the core mass of body supported by the pelvis preempts the possibility of the substantial side-to-side motion that hip adduction would otherwise require by forcing the support leg to tilt-in. Instead, the overpowering mass of body's torso forces the pelvis to tilt down toward the supporting leg, thereby making the leg more vertical, and allowing the running body to move forward in the most energy efficient way. Without this automatic response, incapacitating leg crossover would occur between the legs.

Both pelvic tilt and leg crossover are unnatural, and both are directly caused by the adverse effect of elevated shoe heels on the subtalar ankle joint. Every individual compensates for this reality in a slightly different way, but both ankles, knees, and hip joints on both legs are affected to some extent.

The Dramatic Differences of Barefoot and Modern Bodies During Running

In the natural barefoot Bushman body running in midstance, in **FIGURE 19A**, you see straight legs pointed ahead, a level pelvis, and a well-defined, relatively straight spine and upright head.

In contrast in **FIGURE 19B**, you see a modern Finnish marathoner also running in about the same midstance position. The Finnish runner displays a bowed-out leg rotated outward, a tilted pelvis, deformed bent-out spine with shallow definition and back (with thoracic spinal vertebrae protruding unnaturally between the shoulder blades), and a head tilted-down to the right – all deformities typical of the shoe heel-deformed modern body. (From a May 26, 2013 video clip on **YouTube** titled "**Barefoot running Bushman versus me (shod Finn)**" – see https://www.youtube.com/watch?v=H1Ej2Qxv0W8.

Similarly, the only **YouTube** video clip I could locate of a Western barefoot runner who had never worn shoes was of Zola Budd. It is https://www.youtube.com/watch?v=FGSjpUIGbZs and is titled "**Zola Budd 'world record' 2000 metres**." Unfortunately, the quality of the 1980's era video is very poor. The best still photo I could extract is **FIGURE 20A,** which at least indicates barefoot Budd's straight leg and level pelvis in comparison to the modern Western runner slightly behind her with tilted pelvis and leg.

In clear contrast to Zola Budd, even the most elite modern athletes who have grown up in convention heeled footwear, like Roger Bannister breaking the 4-minute mile barrier **(FIGURE 20B)**, demonstrate a misaligned and deformed body structure under the duress of maximum effort, unlike the upright and aligned body structure of the barefoot Bushman of **FIGURE 19A**. This suggests the potential for much better human performance in the future.

Again, new field work is necessary to video barefoot Western/Caucasian runners who have never worn shoes. I am hopeful that researchers may be able to locate some such runners in the South Pacific. Also, many of the population of India are Caucasian and have been barefoot throughout life (unfortunately, though, most of those affluent enough to be active "runners" have had extensive exposure to modern athletic footwear).

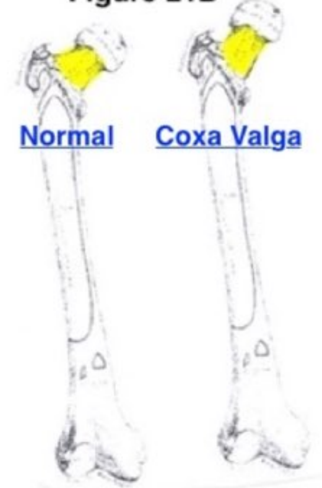
The Functionally Twisted Modern Runner Is a Moderate Version of Permanently Twisted Scoliosis

The functionally twisted skeletal structure of the modern runner above right in **FIGURE 19B** shows the early stages of the same kind of structural deformities that are found in a more exaggerated form in a disease called scoliosis, shown in the photograph of **FIGURE 21A**.

Scoliosis, in fact, provides an extreme case for what passes as "normal" in the abnormal modern human body. The twisting effect of shoe heels creates the same kind of unnatural asymmetrical spine twisting as scoliois in most modern bodies. A study by Gardner et al. indicates that mild asymmetry of the torso is so common as to be "normal" in adolescents, with about half having a 5% to 10% thoracic curve even when young; a study by Akel et al. found that only 19% of non-scoliotic children had level shoulders.[16A]

The widespread epidemic of back pain is the direct result of an unnaturally asymmetric spine. This condition affecting nearly 30% of all U.S. adults each year. Even fit adults, such as the relatively recent examples of NBA Warriors Coach Steve Kerr and Golfer Tiger Woods, can remain functionally incapacitated for years after back surgery.

Figure 21B



In addition, scoliosis is associated with the femur neck inclination known as coxa valga. Coxa valga is a condition in which the angle of the femur neck is greater than 125 degrees, seen on the coxa valga femur in **FIGURE 21B**. Coxa valga is associated with hip adduction. Scoliosis is linked to hip adduction too, like the abnormally exaggerated hip adduction in running shown in **FIGURES 17C & 18B**.

These correlations suggest the strong possibility that running with shoe heels is the underlying cause of scoliosis for those predisposed to the illness, predominately women, whose hips generally adduct more in conjunction with greater pelvic tilt, as shown in **FIGURE 18B**. The result is abnormal hips more prone to fracture.

The blind, moreover, who in the past have not been able to run, do not typically get scoliosis (or at least did not during the period before guide runners became an option).

The Twisted Posture of Young Modern Runners Looks Like Elderly Stoop

Although severe scoliosis is relatively rare, aging effects posture in a similar way because of the long-term damaging effects of shoe heels. See **FIGURES 22 A&B** and note particularly the typically crossed legs shown in **FIGURES 17C & 18A&B** that are obviously a direct effect of shoe heel-induced supination and the resulting knee cant that was discussed earlier in this article.

Substantial Asymmetry Is Universal in the Abnormal Modern Human Body

Heretofore, all biomechanical studies of the lower extremity during running tested only one leg, but a precedent-breaking 2017 study by Radzak at al.[10D] specifically collected data on both right and left legs to evaluate asymmetry during running. The differences they found were astounding.

The range of motion for the average **left** ankle of runners was everted (roughly like pronation) about **32°** and inverted (like supination) only about **3°**. In contrast, the **right** ankle everted about **16°** and inverted about **12°**.

Most runners, in other words, when running do nothing except pronate with their left foot, but pronate and supinate almost equally with their right foot. That is an extraordinary imbalance!

As a result, as seen in **FIGURE 22C** (based on previous **FIGURE 5A**), the left more pronated foot and ankle of most runners will be lower than the right more supinated foot and ankle. This height difference creates a lower left leg and higher right leg during running. The difference initially is probably just functional, but over time the asymmetry worsens into a structural defect. That abnormal leg length asymmetry biomechanically creates in turn an unnaturally asymmetric pelvic tilt.

Note also that both right and left ankle bones are rotated to the right (see red arrows) relative to the heel on the ground, in abnormal compensation to the shoe heel-induced misalignment problems illustrated in **FIGURE 10** and **FIGURE 11A**. This means both right and left legs are shifted unnaturally to the right relative to the pelvis when those legs are maximally flexed and loaded during running, as shown previously in **FIGURE 17**.

Also in the Radzak study, a similar structural asymmetry exists between the right and left knees. The average left knee has a maximum varus (bow-legged) position of about **11°**, but the average right knee has only about a **5°** varus position. **The varus position of the right knee is therefore less than half that of the left knee.**

The reported hip joint differences by Radzak are much less, but that is because they apparently ignore the critical pelvic tilt and only report differences relative to vertical, which ignores the actual adducted angle of the femur relative to the pelvis. Even so, **the right hip angle is cut in half in a fatigued state**, whereas the value for the left hip remains about the same in the rested state, as do the above knee and ankle measurements.

Although limited to walking, a related study[16B] by Lambach et al. indicates that more than half of the overall healthy population exceed **10% asymmetry** between right and left limbs in peak hip and knee adduction and flexion moments (or joint torques). In addition, group medians exceed 10% asymmetry for all variables in all populations.

Genetic Differences Are Minor but Grossly Exaggerated by Shoe Heels

Just like sex differences, otherwise minor genetic differences are abnormally exaggerated by elevated shoe heels. Like the difference between barefoot Islander and shod modern European footprints shown in **FIGURE 1B,** most other distinguishable anatomical differences between the shod modern European and historically barefoot populations are directly caused by regular shoe heel use or complete lack thereof.

Recent genetic studies support this conclusion. The studies underline that all humans alive today – who in the last few thousand years have shared only a small pool of ancestors – retain close genetic connections.[17]

In the unique example below (taken again from an old and obscure, but authoritative medical source), the same individual Caucasian male demonstrates that a simple **realignment** of his legs from **knock-kneed FIGURE 23A** (an alignment more typically found in those of African descent with lower longitudinal foot arches or pronated feet) to **bow-legged FIGURE 23B** (an alignment more typically found in those of Caucasian descent with higher longitudinal foot arches or supinated feet).

The only true genetic difference between the two is an otherwise inconsequential difference in foot longitudinal arch height[18], but that almost undetectable genetic distinction is made unnaturally exaggerated by elevated shoe heels.

That simple leg angle re-alignment from knock-kneed to bow-legged drastically changes the resulting thigh musculature along the same typical lines of genetic background. The genetically distinctive difference in leg musculature is strictly determined only by the surgical change in varus/valgus leg angular alignment of the same individual, and clearly not by genetics, as shown by **FIGURES 23A&B**.

The knock-kneed position of **FIGURE 23A** is mechanically linked by the iliotibial tract of **FIGURE 13A** to the forward-tilted pelvis shown previously in **FIGURE 13C**. The increased quadriceps muscle development of **FIGURE 23A** is therefore also associated with reduced patellar tendon force in jumping and decrease in knee pain.[19]

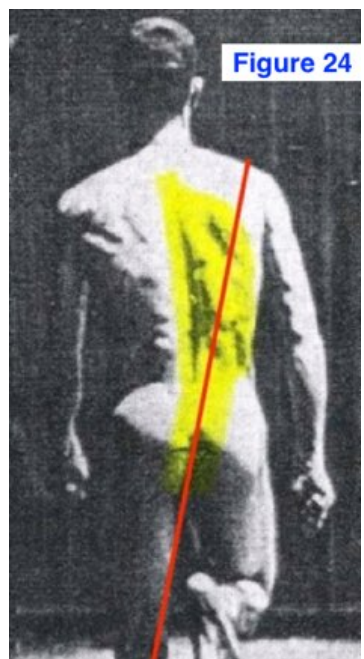
Vastus Lateralis Muscle Is Hyper-developed on Knock-kneed Legs (on Left) and Under-developed on Bow-legged Legs (on Right)

As noted in **Endnote 11**, individuals with lower longitudinal arches **(FIGURE 23A)** are less affected by shoe heels because their lower subtalar joint axis reduces the amount of tibial rotation in the transverse (horizontal) plane relative to pronation and supination during running.

That reduction in tibial rotation lessons the amount of rotary torsion built into the structure of the modern knee joint of low arched individuals. As a result, their knee joints more closely resemble the natural barefoot knee joint in **FIGURE 9B** instead of **FIGURE 9A**.

The Precursor of Heart Disease?

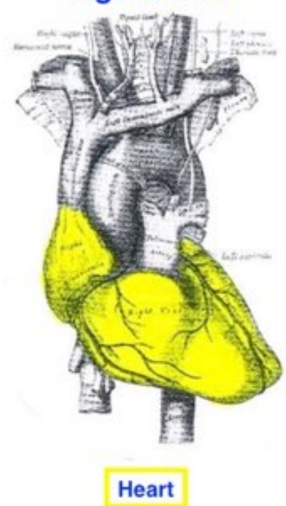
Running gives an early start to the misalignment deformities that we develop more fully in old age. The torsional distortions in the chest area are often substantial, as seen in **FIGURE 24**, and they likely create unnatural pressure on the modern heart



Abnormal Chest Distortion Causes Unnatural Pressure on Heart and eventually heart disease.

Similarly, the stooped chest posture of the elderly, as seen in **FIGURE 22B**, and the increased thoracic spinal curves of men and women, as seen in **FIGURES 13B&C**, also are unnatural distortions that produce abnormally increased pressure on the modern heart.

Figure 24A



The distortions in bone and muscle appear to be much greater on the right side. The focus of the distortions on the right side may generally protect the left side-oriented heart. Because the pelvis is tilts down substantially to the right, the spine is actually curved far to the left side relative to the pelvis, as seen in **FIGURE 24**.

As a result, the abnormal torque and excessive pressure may focus directly on the modern heart, creating abnormally high pressure on the heart, with its highly complex and delicate plumbing network of valves and arteries, as seen in **FIGURE 24A**.

That pressure unnaturally distorts and stresses the modern heart, especially at the midstance in the running stride when the body is subjected to a peak multiple of body weight.

Previous **FIGURE 17A** and **FIGURE 19B** show the same unnatural chest distortion and pelvic tilt. Like **FIGURE 24**, it demonstrates substantial pelvic tilt, which increases the extent of overall structural abnormality, particularly in the thoracic region.

Natural Human Performance Has Much Higher Limits

Performance that we now regard as exceptional is actually much closer to the natural norm of human potential. We fail to realize this only because our current, shoe-heel-induced deformities anchor us well within unnatural limits. This 1960's photo in **FIGURE 25** of the barefoot limbo king of New York City provides a real example of extreme human performance. But all humans have the same genetic potential to come much closer to it than our current expectations have been conditioned to allow by our existing unnatural limitations.

The Effect of Shoe Heels on the Modern Head: Just Like the Knee

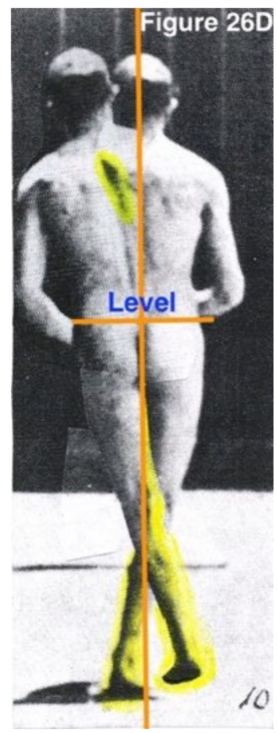
The body part most unexpectedly affected by elevated shoe heels could be the human organ farthest away from the heels: the human head. The motion of the head while running with shoe heels exaggerates all the abnormally asymmetrical motions of the unnatural body beneath it.

In effect, the skull is tip of a skeletal whip in which the subtalar joint is the handle controlling abnormal motion. The natural stability system of the human neck – its highly complex structure of muscles, tendons, and ligaments, including its unique nuchal ligament – are overpowered by the excessive instability of the supporting body below it.

Instead of normal jiggling head motion that can be naturally dampened, the modern head is forced into gyrations that cannot be voluntarily controlled. Instead of a natural position, which would be vertical and forward-facing, the modern skull and the brain within it are twisted abnormally even in the most elite modern athletes in all three planes of motion (**FIGURE 26A).**

Famous photos of Jim Ryun (**FIGURE 26B**) and Roger Bannister (**FIGURE 26C**) setting world records in the mile both indicate abnormal, intensely twisted head motion. While these head motions may be extreme but only the occasional result of intense effort, they are actually just exaggerated examples of continuous everyday abnormal motion that has become embedded over time. In somewhat reduced form, the unnatural twisting motion recurs repetitively on a routine basis throughout modern human life, especially in the early, formative years. (**FIGURE 26A**).

As shown in **FIGURE 26D**, the upper torso of the modern body is whipsawed back and forth between each tilted-in leg at the point of maximum load during running, relative to a level pelvis. The effect of this unnatural whipsawing motion is structurally greatest at the head, making it abnormally unstable.



As seen in **FIGURE 27A**, multiple World Record Holder and Olympic Sprint Champion Usain Bolt's head tilts significantly to the left at midstance on one leg when he is running. In contrast, his head is more upright at midstance on the other leg. This extreme degree of left/right asymmetry is remarkable in light of his unprecedented level of athletic performance.

Bolt’s tilting head motion suggests that such asymmetry (or more) is widespread throughout the modern human population, although biomechanics studies on running have not studied the issue in the past. For example, even the unusually comprehensive study by Radzak et al. noted above,[12] which uses 27 reflective markers located over most of the test subject’s body, including both sides, has no markers on the cervical spine nor on the skull.

Bolt’s high degree of asymmetry also suggests that his incredible sprint performance probably does not approach the maximum limit of natural human potential. His asymmetry is probably due to his use of conventional athletic shoes after a barefoot childhood in Jamaica.

The typical leftward tilt of Bolt’s head during running midstance (shown on alternating legs) must alter the permanent structure of the cervical vertebrae of the neck. Over time those vertebrae bow out in order to accommodate the asymmetrical position and load. For a typical example (not Bolt) of this unnatural modern cervical structure, see **FIGURE 27B.**

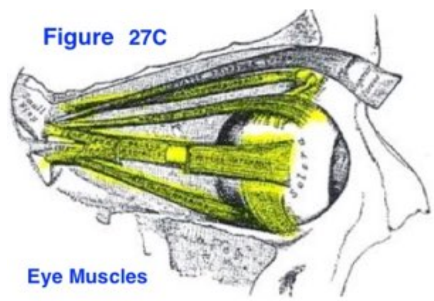
As **FIGURE 27B** demonstrates, the asymmetrical position of the modern cervical vertebrae - bowing out to the right to compensate for the leftward tilt of the modern skull - becomes quite evident even when the body remains at rest in a stationary position. In addition, arterial hyper-development on the right side appears to be abnormal, potentially indicative of eventual future stroke. And **FIGURE 27B** is just a typical example taken at random of modern neck structure.

Eye Control Illustrates the Structural and Functional Problems Within the Abnormally Supported Modern Skull

Vision issues may help us understand the unnatural deficiencies inside the modern skull. The most common modern vision problem is near-sightedness (myopia), a condition results from an abnormal elongation of the eye.

The modern skull is typically bent backwards as noted above (**FIGURE 26A**) by the excessive curve of the cervical spine. As a result, the force of gravity is directed more toward the rear of the skull, which will increase pressure on the back of the eye. That unnatural pressure over time gradually tends to lengthen the eye (and continues over time), thus moving the retina at the back of the eye backwards and rendering it increasingly out of focus.

If the skull is also bent sideways, then that distortion creates asymmetry between the right and left eyes. Any other unnatural twisting motion will create the abnormal skull motion is in all three dimensions. The result is asymmetry within either or both eyes (astigmatism), and as well as different levels of myopia in each eye. Note the complex and delicate structural arrangement of the muscles controlling the eye shown in **FIGURE 27C.**



Similar mechanisms underlie all the other deficits inside and outside the skull. These adverse effects may involve the size and shape of the sinuses and associated problems such as deviated septums, the malalignment of teeth, the malalignment of the jaw with the skull, and various hearing difficulties. There are, of course, there are no known direct causes for any of these listed head-centric problems. By default, the accepted current wisdom is that these deficiencies just happen; we are told, for example, that excessive reading causes poor eyesight, or that a congenital defect causes the deficiency.

The Asymmetrical Structure of the Modern Brain Shows the Same Abnormal Rotary Torque as the Unnaturally Twisted Modern Knee: Is That a Coincidence?

Base on the foregoing, it is even possible to speculate that elevated shoe heels have rendered the modern brain more bilaterally asymmetrical. Modern neuroscience had firmly established in that the modern human brain has a shape and structure that is **asymmetrical, with the right hemisphere shifted forward and the left hemisphere shifted backward**. This modern brain asymmetry is indicative of the very same unnatural rotary torque that is built into the modern knee joint, as previously seen in **FIGURE 9A**.

The well-known structure of the **modern human brain** is shown in **FIGURE 28A.** The modern human brain is twisted, showing an abnormal built-in structural reaction to unnatural rotary torsion in the shifted positions of the right and left hemispheres, as shown in a bottom view, with the right hemisphere shifted forward.[20]

So, it is possible that the right hemisphere brain shift is either caused by elevated shoe heels or the shift is increased by them. However, if the shoe heel-based evidence already presented is ignored, it might be reasonable to assume that this brain shift is solely or at least partly due to the predominance of right-handedness. However, the only evidence available now does not support this explanation. Instead, the few pre-modern brain drawings in existence show highly symmetrical brains, albeit with a slight hemispherical shift in the opposite direction from modern brains.[21]

Why Going Barefoot Is Not the Solution for Most Modern Human Bodies

Shoe heel-wearing sufferers with the physical abnormalities I have already discussed face an unfortunate reality. Once their individual abnormalities become well developed over time, those changes become locked into actual bone structural changes in the foot, ankle, knee, hip, pelvis and spine. Those joints become permanently malformed to a degree that varies between individuals. Even totally avoiding elevated shoe heels does not eliminate the problem.

As I noted earlier, the footprints clue cited in the old James report (**FIGURES 1 A&B**) provides us with especially helpful evidence because the footprints were taken with the individual's knee bent forward, with the individual supported on that single leg alone. The print thus was taken in the typical midstance running position shown in **FIGURE 7** (although loaded at only one full body weight, rather than the two to three times that is typical of running).

These footprints, moreover, were taken of bare feet. The footprints provide good evidence that normally shod feet continue to roll unnaturally to the outside in the **supination** position even when bare, as **FIGURE 1B** demonstrates. Elevated shoe heels, in other words, have abnormally re-shaped the foot and ankle bones, and associated ligaments, muscles and tendons.

Simply going barefoot – the easy and inviting solution – will therefore worsen rather than resolve these deformities, at least for many individuals. Individuals whose shoe heel-induced deformities are worse than average will face significant adjustment problems if they attempt to run barefoot.

Over a lifetime, elevated shoe heels build a veritable house of cards out of the structure of modern human bodies. As a result, those heels have become a built-in, essential structural prop. Pull that prop away and the house becomes unstable and prone to collapse, at least partially, and particularly in the form of increased bilateral asymmetry.

Unfortunately, those who need help the most are the least likely to get it by going barefoot. Only those with less of a structural problem to start with are likely to be able to transition safely to barefoot running and benefit from it.

This is why running shoe design is currently at a dead-end. There is no easy or immediate solution available currently. There is not even a known solution. Those individuals most in need have no known satisfactory footwear options. At best, only a very slow and gradual transition to lower shoe heels holds any hope of success.

Smartphone Control of Configurable Shoe Sole Structures Will Provide the Solution, With Help from the Cloud

I do not believe that it is possible, with current methods, to find a specific solution for each individual's shoe heel-induced structural problems. I think a comprehensive solution will require high technology in the form of shoe soles with sensors and configurable structures that are controlled by the wearer's smartphone connected to clouds of computers. Artificial intelligence that utilizes machine learning techniques – typically referred to as "deep learning" - must be applied to the big data received from, at first, hundreds, then thousands, and eventually many millions of wearers.

As an inventor, I filed U. S. and international patent applications, and received a U. S. Patent on this approach in technology, Number US 9,030,**335**, on May 12, 2015. The title of the patent is "**Smartphone App-Controlled Configuration of Footwear Soles Using Sensors in the Smartphone and the Soles**." It is also available to view on the Internet at my website: **www.AnatomicResearch.com** or at the **USPTO** website, together with eight new and directly related patents: US 9,063,529, US 9,100,495, US 9,160,836, US 9,207,660, and US 9,375,047, US 9,504,291, US 9,709,971, and US 9,877,523. Others are pending.

A short time after I was awarded my first smartphone-controlled sole patent, my business partner's wife inadvertently discovered during an Internet search an unsolicited but highly laudatory third-party **YouTube** video complete with animation on my newly issued '**335** patent. It was a complete surprise to us. The patent was singled out from many thousands of other patents for unusual praise. You can see it by searching for the title, "**Smart Shoe – finally humanity invents the shoe that it deserves**", or at the link: **www.youtube.com/watch?v=CjBhghWDMoM.**

One of the interesting features of this new dual smartphone and smartsole technology is that it empowers millions of users to become active **citizen scientists**. Users can contribute the critical mass data needed to provide the basis for the most effective solutions to asymmetric biomechanical imbalances. Their smartphones can provide a real-time user window into the entire process via the smartphone and empower the user to retain overall control of their own personal system.[22]

Lack of Privacy and Security of Highly Personal Data in Smartphones & the Cloud: An Insurmountable Problem?

A major roadblock, however, threatens the potentially indispensable new approach I have just described. There is simply no safe way to create and store this sensitive personal data, not currently and not in the immediate future.

The continual theft of huge databases from both businesses and government provides constant proof of this never-ending and ever-increasing problem. Your smartphone and personal computer – like all other computers, including the cloud - similarly lack reliable protection.

Current approaches in cybersecurity - all based on software – are inherently vulnerable and cannot be fixed with better software, even in theory. A basic change at the most fundamental possible level of hardware architecture can provide a practical, foolproof solution to this otherwise intractable problem.

I provide more information on this problem and solution in Chapter 34 of my draft book under the "**Research**" tab at my footwear website: www.AnatomicResearch.com. You may also visit my computer security architecture website: www.GloNetComp.com.

The Only Immediate Physical Relief: New Forms of Stretching and Exercise That Specifically Counteract the Adverse Effects of Shoe Heels

It will, unfortunately, take time for anyone to develop and commercialize this technology on a widespread basis. The process is likely to take several years.

In the immediate future, the only available relief in sight does not involve footwear. Instead, new forms of stretching and exercise are in the process of being developed and tested that specifically target the particular problems caused by shoe heels.

Preliminary results suggest the high potential of several approaches to provide substantial relief from the adverse effects of shoe heels. Several stretching and exercise approaches even look promising as possible "magic bullets" in terms of providing dramatic personal improvements.

I will post demonstration videos will be posted on my website, www.AnatomicResearch.com, as soon as they become available.

For now, if you are a diehard runner, like most, I would make two suggestions. First, switch to alternating between running and walking, or run/walking, instead of continuous running or jogging.

Second, run on one day, and switch to strength building and stretching on the other day. You should aim for equal amounts of running and strength building/stretching.

Obviously, you can add some other non-running aerobic exercises such as cycling or rowing can also be added into the mix, as well as variable direction running sports such as soccer, basketball, and tennis, for examples.

What Approach to Take in Choosing Between Shoes and Going Barefoot

Switching between the use of shoe heels and bare feet, especially in rigorous sports and exercise, is itself a likely source of injury. The risk becomes especially high when a runner goes barefoot and then wears conventionally heeled shoes immediately before and after the run.

To avoid this problem, your transition to lower heels must be slow and gradual, taking as long as a year.[23]

Instead, the best you can do for now is to try to moderate the adverse effects of elevated shoe heels. To do that, you should avoid shoes with higher heels, and this includes both athletic and street shoes. You might even try moccasins or slippers with low heels, instead of flip-flops or going barefoot.

The basic idea is to try to reduce the amount of change or transition between different heel heights by converging toward the middle between the highest and lowest extremes, in terms of heel heights. The heel should be neither too high nor too low.

This approach is particularly important for women who choose to wear high heels, especially very high spiked heels. In my view, you must come down gradually from these higher heels, especially if you are a serious athlete.

I believe that high heels present a serious health problem for women. I realize that high heels create an important fashion statement, and many women have a strong desire to wear them, apparently for sexual allure more than anything else, according to surveys. Strictly on a biomechanical basis, sexier clothing is a better choice than high heels, if the desire for allure predominates.

Only the Very Young Can Go Barefoot Without Hesitation – Most Who Are Older Are Already Too Deformed

In contrast to adults, for the very young – those whose bodies have never been adversely affected by elevated shoe heels -- the solution is simple. Young children – and only young children – best preserve their natural physical health when they go barefoot or wear the most minimal of shoes without elevated shoe heels.

For their brain health, it is critical that children engage in adequate exercise every day. As I have already noted, the brain evolved specifically to make motion possible. The coordination of body movement remains its primary function.

Your children should receive at a minimum a full hour total of recess time or physical education at school. If they are not getting this critical exercise, organize with other parents and demand it! Nothing else they could do in that exercise hour will help as much to promote their ability to learn.

Massive Medical Expenses

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. That figure translates into an absurd dollar amount per shoe. Every pair of modern shoes sold today may well generate over $1,500 in medical costs. (This rough estimate assumes that $100 is the average price per pair).

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.

A True Moonshot on the Magnitude of the Original 1960's Moonshot Is Far More Justified Than the Original

Today we routinely overuse the term "moonshot." We attach the term to too many projects that are unlikely to achieve tangible benefits in the foreseeable future.

In this case, however, our difficult circumstances fully justify a 1960's moonshot-level project to address the massive medical problems caused by elevated shoe heels. The real-world benefits we would gain here on planet Earth from a "**Human Anatomy Moonshot"** would likely dwarf those that we accrued by our visit to the moon. There is no other project that presents us with anything close to the same "bang for the buck."

The First Step: A Center for Theoretical Human Anatomy

Nearly all of the fields of research that are needed to address the medical problems described in this article are located in a large number of different and unconnected commercial, academic, medical, and governmental silos, all separated by specialty and/or organization. No single entity anywhere today has anything like a complete picture of the overall problem or the means to solve it.

Numerous organizations are needed to cooperate effectively to successfully accomplish the required moonshot I have suggested. A partial list would include the major footwear companies, high tech companies including smartphone, social media, database and cloud companies, research universities, medical care and research facilities, public and private foundations, as well as American, foreign, and international government research and regulatory entities.

Many medical and scientific fields also would need to coordinate their efforts. A partial list of specialties that similarly must cooperate effectively include anatomy, biomechanics, physical anthropology, orthopedics, podiatry, as well as computer and network technology, including hardware, software, and robust cybersecurity.

The United States government – specifically NASA – ran the 1960's moonshot. The project was huge and expensive, but tangible non-lunar benefits that would not have occurred anyway are difficult to identify. Many major government-led research projects, of course, have accomplished far less than the 1960's moonshot, and some have been called outright fiascos.[24]

In my view, a private non-profit foundation focused on overall coordination - a new **Center for Theoretical Human Anatomy** - funded with mostly private and some government support, can do much better. While spending far less, it could achieve immeasurably more for humankind.

A Human Anatomy Moonshot could improve billions of lives and save trillions of dollars in medical expenses every year.

Major University Departments Dedicated to the Study of Footwear, Especially Sole Structure

Shoe soles literally form the artificial foundation of the modern human body. They control the development of its structure and thereby its function. Shoe designers, however, have no formal academic training in footwear technology; they only receive on-the-job industry training. These designers are completely unprepared to function as architects of the modern human body. Currently, they are oblivious to the profound consequences of their work on the structure of the human body.

No meaningful shoe sole design standards or regulatory oversight exists now, so widely varying structural shoe sole products are tested on the public with no practical restraint. The design of shoe lasts, essential to the manufacture of footwear, is generally considered a "black art" understood only by a priestly few, who are just as unconscious of the consequences of their work as shoe designers.

Building architects, in the starkest of contrasts, are all graduated from formal academic programs in well-established universities. Over 60 architectural programs exist in the U. S. alone and almost 700 worldwide. Associated credentialing, licensing, building codes, and inspection carefully control every architectural structure they create, from home renovations to the tallest skyscrapers.

Therefore, an essential, permanent part of the Human Anatomy Moonshot is the funding and establishment of many new major footwear university departments to serve as that critical missing academic foundation for footwear research, design, and manufacture.

Neuroscience and astronomy, for two examples, receive vastly more research funding today than gross human anatomy or the biomechanical study of the human body in motion, particularly in the field of running, despite the need for reliable answers to the urgent questions raised in this article. University biomechanics labs are currently so massively underfunded and therefore under-staffed and under-equipped that their research results are of limited practical use, if any, as discussed at length in Endnote 11.

The Major Moonshot Goals

The Moonshot's <u>first</u> major goal would be to discover for the first time, and as quickly as possible, exactly what is the true natural human body: a detailed and accurate understanding of its structure and function in the strict absence of the artificial effects of footwear, especially elevated shoe heels.

The Moonshot's <u>second</u> major goal would be to develop the most effective treatment modalities for all modern humans who continue to suffer from the adverse effects of past use of shoe heels on every part of their bodies. Included in the goal would be to find and implement new and practical technological solutions, such as the shoe sole structures that are more naturally shaped like the barefoot sole and/or dynamically configurable by smartphone and cloud using a feedback loop of data from sensors located in the shoe sole and in other sensors located on the body, including the head.

The Moonshot's <u>third</u> major goal would be to identify the beneficial and/or adverse effects that conventional footwear has imposed on the human brain, and to determine whether such benefits could be maintained or increased, while at the same time decreasing or eliminating the adverse effects of shoe heels.

Start Up of the Theoretical Human Anatomy Center

The coordinating non-profit foundation, the Center for Theoretical Human Anatomy, needs to start up as quickly as possible. I am willing to contribute my time to the Center and also my extensive patent portfolio of over 100 U.S. and foreign patents that enable most of the new technologies that I believe are required for success.

I will allow my patent portfolio to be freely used by all companies that provide reasonable financial support and operational cooperation to the Center sufficient for it to function effectively, commensurate with the Center's role in providing focus and coordination to the Human Anatomy Moonshot.

This financial requirement is both modest and reasonable. Commercial development and use of my patent portfolio will be quite profitable for these companies and will solve (or reduce as much as possible) fundamental problems in the existing commercial products upon which they depend.

The Center will need private individuals and organizations immediately to provide initial startup funding and infrastructure in order to jump-start the Center's critical coordination.

The Center also will need a core group of key leading experts to leave their disconnected individual specialty silos now to focus together on the goals of the Human Anatomy Moonshot. The Center needs an effective working group with highly qualified researchers willing to share their knowledge in order to generate the solutions that will make this Moonshot a success.

The Limiting Factor in Modern Medicine: Treating Symptoms Instead Providing Prevention or Cures

As I have already shown in detail, the elevated shoe heel bio-mechanism has degraded the structure and function of every part of the modern human body. The mechanism has changed the body from natural to abnormal, and from strong to weak. As a result, adverse health effects logically should occur throughout the modern human body, so it is difficult to imagine any human medical problem that the elevated shoe heel has not made worse.

The shoe heel's effect, however, may be even greater than we know. From arthritis to back pain, from heart disease to sexual dysfunction, even from cancer to constipation – in fact, with almost every non-infectious disease occurring throughout the human body – every one of these disorders represents a disconnected effect with no known direct cause.

The consensus of expert opinion is generally that these diseases just happen, many due to weakness in the design of the human body as it evolved, and therefore nothing much can be done about that.

In consequence, without an understanding of specific known causes or underlying aggravating factors, modern medical care must resort to trial and error methods to treat the symptoms of disease, instead of directly curing or preventing the disease itself.

Most major human diseases today remain unprevented and uncured, despite the constant introduction of a vast array of new medical technologies and drugs that do treat their symptoms far more effectively, but often at great expense. Those innovations in health care are very real and continual, and they save or improve countless lives, but they typically emerge as incremental advancements rather than breakthrough cures or prevention.

In this article, I have made a strong case for a single unifying factor that accelerates or even initiates the progression of many of these non-infectious diseases. An unnatural physical weakness that results from the specific debilitating effects of shoe heels is the potential common link for many or even all of these disorders, allowing them to have an unnaturally greater adverse effect on the modern human body.

Even where the biomechanical effect of shoe heels clearly does not directly cause a disease, their effect may substantially weaken the body's ability to function naturally to defend itself. That has made the body much more susceptible to infections or communicable diseases and unnaturally less able to fight them effectively.

Finally, elevated shoe heels have rendered the human body more vulnerable to all types of injury, whether from incidental accidents like ankle sprains or long-term overuse, like repetitive stress injuries.

Elevated Shoe Heels Cause a Gross Mismatch Disease

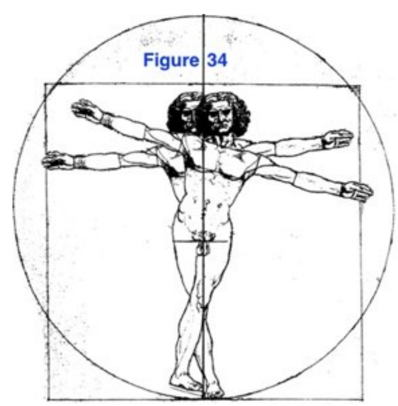
Humans evolved barefoot, but in the modern world they are **mismatched** by that evolution with a critical part of their modern physical environment – elevated shoe heels. The result is the physical evolution-in-reverse of modern *Homo Sapiens*.

The few remaining barefoot hunter-gatherers still in existence are almost immune to most of the noninfectious diseases that kill or disable modern humans, as Dr. Daniel Lieberman notes in his book, ***The Story of the Human Body***. Liebermann notes that the limited study data available indicates that barefoot middle-aged and elderly hunter-gatherers (who typically live to an age between 68 and 72) remain remarkably healthy:

> ...[they] rarely if ever get type 2 diabetes, coronary heart disease, hypertension, osteoporosis, breast cancer, asthma, and liver disease. They also don't appear to suffer much from gout, myopia, cavities, hearing loss, collapsed arches, and other common ailments. …they are healthy compared to many older Americans today **despite never having received any medical care**.[25] [emphasis added]

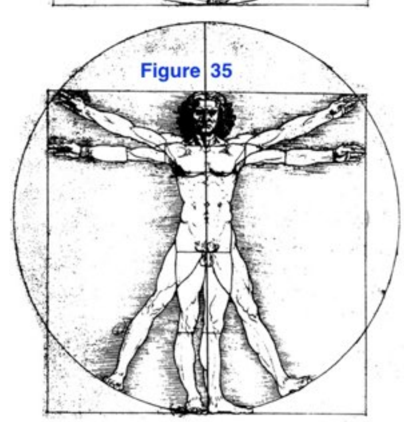
This remarkable conclusion echoes that from over three decades ago in a study by a Canadian researcher and physician, Dr. Steven Robbins and a colleague. His study that surveyed the available literature on the injury history of barefoot populations[26].

What Dr. Robbins found was that those barefoot populations representing genetically diverse human populations had far fewer overuse injuries than were typical of modern shoe-wearing populations. Even more attention-grabbing was that this was far fewer injuries despite far higher activity levels on a routine basis, often including what would be called back-breaking work in the modern world.



The elevated shoe heel bio-mechanism and its adverse effects potentially constitute a real **Black Swan** event in human anatomy and medical care.

The heel mechanism has fundamentally changed the modern human body from symmetrical and robust to the asymmetrically deformed and fragile body shown in **FIGURE 34**. The deformed modern body has abnormally bent-in legs that forcibly tilt an unstable pelvis. The result is an unnaturally bent-out spine and tilted-in head in the peak load running position, shown in **FIGURE 26D**, in which the bone and joint structure of the modern human body is deformed unnaturally by elevated shoe heels, in accordance with Wolff's and Davis's Laws.



The study of modern human anatomy must adopt a **new paradigm** of the human body. That new paradigm must be based on the understanding that the true natural structure and function of the **barefoot human body** is the natural norm – the bilaterally symmetrical, theoretically ideal body, shown in **FIGURE 35**, that existed before elevated shoe heels came into widespread use. The existing anatomical paradigm - the modern human body deformed by shoe heels – must be redefined as an abnormal diseased state.

Shoe Heels Create Broken Bodies and Weakened Brains, But Some Better, More Specialized Brains

In summary, elevated shoe heels have adversely effected the structure and function of every portion of the modern human body, including the brain. Shoe heels ironically may have enhanced the brain's highest functions, at least for some individuals. General cognitive defects, however, in the form of dementia and many other mental illnesses may far more than offset this gain.

Gross human anatomy has long been considered the most settled of all the sciences. All of its mysteries have been thought to have been solved, most by at least a hundred years ago. However, that assessment now appears to be quite wrong.

Our centuries-old understanding of normal human structure and function is incorrect. It is based on the mistaken belief that abnormality of the modern human body is the natural normal, instead of an artificial state of unnatural disease caused by elevated shoe heels. The fragmentary state of available information on that natural norm, moreover, makes it currently impossible for us to understand what is true natural human anatomy.

Failure Is Not an Option

Far more than saving the Apollo 13 moon mission is at stake in the Human Anatomy Moonshot. An incalculable number of serious medical problems and human lives are at risk, so the famous mantra that **"failure is not an option"** must now be an ironclad rule!

There really is no way to describe the untenable situation that we, as modern shoe-wearers, are all trapped in, 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 (that was unnaturally formed and less-than-normally 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.

This article, which is an abridgement of the book referenced below, is a first attempt to communicate at least a rough description of the trap we are in, with as much detail as currently possible. It is the first step in finding the fastest and least costly way for all of us to escape at long last, and finally gain real control over the fate of our physical beings.

It is therefore urgent that we, for the first time, focus on the true cause – elevated shoe heels – of this global mass epidemic of 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.

The Details Are Available in the First Draft of the Book

To recap, we really know very little about the anatomically normal human body. Only fragmentary sources of good information are currently available to us. We can, however, make educated guesses based on good evidence.

For more on this subject, see the surprising story that follows in the more detailed first draft of my new book. The complete book area is available at my research website, **www.AnatomicResearch.org.** You will also find highly detailed **Endnotes** there, which list all of the hundreds of peer-reviewed references cited in the book, and other associated materials, as well as many supporting **Selected Video** clips.

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 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 notes the exact pages and/or figures that were considered most relevant. Far more articles were reviewed and deemed not sufficiently relevant to include.

ENDNOTES

1. Please pardon the offensive references to "native" used in this old study. The study unfortunately reflects the racist language typical of the Colonial era. The study also refers to the "natives" as "savages," probably in shocked reaction to their headhunting and cannibalism. Both practices remained common in 1939 in the area of New Guinea.

To use slightly more modern terms, the genealogy of the natives is considered Polynesian and the "Europeans" are Caucasian. To be most correct today, you need merely acknowledge that two groups from different geographic areas have some discernible genetic differences.

The study is by Clifford S. **James** and is entitled "Footprints and feet of natives of the Solomon Islands," published in 1939 in the ***Lancet***: 2: 1390-1393. The island in the study, Malaita, is next to Guadalcanal, which in 1942 was the site of famous U. S. Marine and Naval major battles against the Japanese during World War II.

Also of note, a recent study of children indicates that supinated feet are extremely rare in children, numbering only 4%, whereas 70% are neutral and 20% pronated. In only three years, however, supinated feet increased by 19.5%, while pronated feet decreased by 10.6%, presumably indicating the gradual effect of the use of elevated shoe heels. See **Martinez-Nova**, Alfonso et al. (2018). Foot posture development in children aged 5-11 years: A three-year prospective study. In ***Gait & Posture*** 62: 280—284, May.

2. From 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**. (Note: Fig. 6 is not modified, except that for simplicity I have removed the non-human example of (A) a baboon and I also annotated and highlighted portions of the images.)

3. **Bramble**, Dennis M. & **Lieberman**, Daniel E. (2004). Endurance running and the evolution of Homo. In ***Nature*** 432: 18 November 345-352.

4. **McDougall**, Christopher (2009). ***Born To Run***. *New York: Alfred A Knopf*

5. **Shorten**, Martyn (2005). Footwear Biomechanics: What Does the Future Hold? ***The 7th Symposium on Footwear Biomechanics*** of the Technical Group On Footwear Biomechanics of the International Society of Biomechanics.

6. **Nigg**, Benno M. (2010). ***Biomechanics of Sports Shoes***. Calgary, Alberta.

7. **Frederick**, E. C. (2011). Starting Over. In ***Footwear Science*** 3: 2: June 69-70.

8. **Richards**, Craig et al. (2009). Is Your Prescription of Distance Running Shoes Evidence-Based? In ***British Journal of Sports Medicine***, April.

8A. **Napier**, J. R. and **Day**, M. H. (1964). Hominid Fossils from Bed I, Olduvai Gorge, Tanganyika: Fossil Foot Bones. ***Nature***. 201, 969-970. **Hicks**, J.H. (1954) The mechanics of the foot: the plantar aponeurosis and the arch. The ***Journal of Anatomy***, 88 (1) 25-31, Fig. 3. **Hicks**, J.H. (1961) The Three Weight-bearing Mechanisms of the Foot, in F.G. Evans (Ed.), ***Biomechanical Studies of the Musculoskeletal S****ystem*, 161-191, Fig. 23, Charles C Thomas, Publisher, Ltd. **Elftman**, E. (1960). The Transverse Tarsal Joint and Its Control. ***Clinical Orthopaedics***, DePalma, A. (Ed.) 16, 41-45. **Root,** M., **Weed**, J., S**garlato**, T., and **Bluth**, D. (1966). Axis of Motion of the Subtalar Joint. ***Journal of the American Podiatry Association****,* 56 (4) 149-155. **Inman**, V.T. (1976). ***The Joints of the Ankle***. The Williams & Wilkins Company. **Sarrafian**, S.K. (1987). Functional Characteristics of the Foot and Plantar Aponeurosis under Tibiotalar Loading. ***Foot & Ankle*** 8 (1) 4-18. **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, Fig. 10. **Erdemir**, A., Hamel, A., Fauth, A., Piazza, S., and Sharkey, N. (2004). Dynamic loading of the plantar aponeurosis in walking. ***The Journal of Bone and Joint Surgery***, 86-A, 3, 546-552, Fig. 4. **Kelikian**, A. S. (Ed.) (2011). ***Sarrafian's Anatomy of the Foot and Ankle***. Third Edition. Lippincott Williams & Wilkins.

9. **Rubin**, Gustav (1971). Tibial Rotation. In ***Bulletin of Prosthetic Research*** - *Spring* 1971, 95-100, especially pages **96-97**. Dr. Rubin found that each 1° of foot supination resulted in 1.72° of tibial rotation. As we shall see in Endnote **11**, there has been much research, but little agreement on the exact mathematical relationship. However, a 2017 study by Katrina Fischer et al. has now provided the most accurate information currently available.

Limited to only three male test subjects, but actually conducted during running while using intracortical pins to track 6 different foot bones with the highest degree of accuracy, the study found 1.73°, 1.73°, and 1.41° of tibial rotation for each 1° of calcaneal adduction, for an average of 1.62°. Katrina Mira **Fischer**, Steffen Willwacher, Anton Arndt, peter Wolf, and Gert-Peter Brueggemann (2017). Calcaneal adduction in slow running: three case studies using intracortical pins. In ***Footwear Science***, Vol. 9, No. 2, 87-93, especially **page 90** and **Table 1**.

The same researchers, Katrina Fischer et al., conducted an *in vitro* study in 2018 of eight fresh frozen foot-leg specimens. However, that study has a critical flaw, in that the leg was rigidly maintained in a vertical position (a standing or walking position under 0.5-1.0 bodyweight load), instead of dorsiflexed 25° as it would be under peak 2-3 bodyweight load during running (as seen in **FIGURE 7**). Katrina Mira **Fisher**, Steffen Willwacher, Anton Arndt, and Gert-Peter Bruggemann (2018). Calcaneal adduction and eversion are coupled to talus and tibial rotation. In the ***Journal of Anatomy*** 233, 64-72, particularly **page 65** and **Figure 1**. (See also reference to this study in Endnote 11A.)

10. With regard to the static **coupling** mechanisms that are old and "settled science," among the oldest representative example references is Merton **Root**, John **Weed**, Thomas **Sgarlato**, and Daniel **Bluth** (1966). Axis of Motion of the Subtalar Joint. In the ***Journal of the American Podiatry Association*** 56: 4: pages 149-155. See also **Sgarlatto**, T. E. (Ed.) (1971). ***A Compendium of Podiatric Biomechanics,*** pages 40-46. San Francisco: California College of Podiatric Medicine. The most current summary is **Werd**, Matthew et al. (2017). ***Athletic Footwear and Orthoses in Sports Medicine*** (Second Edition), particularly **pages 21**& **35** and pages 19-40 generally. Switzerland: Springer Nature.

With regard to recent **decoupling** studies, see for example **Nigg**, Benno M. (2010). ***Biomechanics of Sports Shoes***. First Edition. University of Calgary: Calgary, Alberta, Canada. See **pages 80-93** for a relatively recent summary on ankle joint coupling between the foot heel and lower limb, as well as cited references on pages 123-129, with added references on pages 129-136. See also, Alex **Stacoff**, Benno Nigg, Christoph Reinschmidt, Anton Bogert, Arne

Lundberg, Edgar Stussi, and Jachen Denoth (2000). Movement Coupling at the Ankle During the Stance Phase of Running. In ***Foot & Ankle International*** 21:3 pages 232-239, particularly **page 232** and **Fig. 5**.

Another good summary: Alison T. **DeLeo**, Tracy Dierks, Reed Ferber, and Irene Davis (2004). Lower extremity joint coupling during running: a current update. In ***Clinical Biomechanics*** 19 (2004) 983-991. A recent coupling reference: Katina M. **Fischer**, Steffen Willwacher, Joseph Hamill, and Gert-Peter Bruggemann (2017). Tibial rotation in running: Does rearfoot adduction matter? In ***Gait & Posture*** 51: pages 188-193. Many other decoupling studies exist in addition to these particularly noteworthy examples.

The latest and most accurate study on running decoupling: Katrina Mira **Fischer**, Steffen Willwacher, Anton Arndt, Peter Wolf and Gert-Peter Brueggemann (2017). Calcaneal adduction in slow running: three case studies using intracortical pins. ***Footwear Science***, Vol. 9, no. 2, 87-93, particularly **Figure 1, page 88,** and **Table 1, page 90**. (A related study is on pages 79-85 of the same reference by Mattieu Trudeau, Carl Jewell, Eric Rohr, Katrina Mira Fischer, Steffen Willwacher, Gert-Peter Brueggemann, and Joseph Hamill. The calcaneus adducts more than the shoe's heel during running.) Finally, see also Katrina Mira **Fischer**, Steffen Willwacher, Anton Arndt and Gert-Peter Brueggemann (2018). Calcaneal adduction and eversion are coupled to talus and tibial rotation. In the ***Journal of Anatomy*** 233: 64-72.

10A. Frederick, E. C. (1984**). Sports Shoes and Playing Surfaces: Biomechanical Properties,** 170 & 179, Human Kinetics Publishers.

10B. Clarke, T.E., Frederick, E.C., and Hamill, C.L. (1983). The effects of shoe design parameters on rearfoot control in running. **Medicine and Science in Sports and Exercise**, 15, (5), 376-381.

10C. Cavanagh, P. R. (1980). The **Running Shoe Book**, 169-170 and Fig. 8.5. Anderson World, Inc.

10D. Radzak, K. N., Putnam, A. M., Tamura, K., Hetzler, R. K., and Stickley, C. D. (2017). Asymmetry between lower limbs during rested and fatigued state running gait in healthy individuals. **Gait & Posture** 51, 268-274. (270-272 & Tables 2-3)

10E. McClay (Davis), I. (2000). The Evolution of the Study of the Mechanics of Running. **Journal of the American Podiatric Medical Association** 90: 3: 133-148. (141 & Fig. 8)

10F. Zifchock, R., Parker, R., Wan, W., Neary, M., Song, J., and Hillstrom, H. (2019). The relationship between foot arch flexibility and medial-lateral ground reaction force distribution. In ***Gait & Posture***, 69, 46-49.

10G. Nigg, B. M. (2010). ***Biomechanics of Sports Shoes***, 21.

10H. In contrast, most modern supinated feet have little or no lateral arch, since they are rolled unnaturally to the outside, bringing the lateral side of the foot down into contact with the ground (but not necessarily with the shoe sole, since the majority of modern shoes soles are cut in at the base of the fifth metatarsal, leaving it unsupported. That is a critical structural flaw that greatly enhances the capability of the modern shoe to cause unnatural ankle sprains, again, the most common sports injury and most common cause of Emergency Room visits.

From Lawrence H. **Wells** (1931). The Foot of the South African Native. In ***the American Journal of Physical Anthropology***, Vol. XV, No. 2. 186-289, particularly pages **247** & **259**.

10 I. 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, Fig. 1. 2, 2325967119826081

11. I sent a copy of an early version of the first draft of the full book version of this article in 2017 to E. C. "Ned" Frederick, Ph.D., for a preliminary review. Dr. Frederick is and has been for many decades one of the best-known scientists in the field of footwear biomechanics. He is the former head of R&D at **Nike** (actually the first) and currently the Editor (also the first) of **Footwear Science**. In addition, he played a significant role in the early 1990's in helping me to license my barefoot-based shoe sole technology to **Adidas**, where it became **Adidas'** core footwear technology for many years (for a fuller story, see www.AnatomicResearch.com.)

Despite a full-to-overflowing schedule at the time, Ned was kind enough to provide a brief initial analysis of my long and complex first draft of a book (which then included over 50 pages of Endnotes). I believe the most important concern he raised in his review was a **decoupling** issue. Although in general the static lower leg bio-mechanism described in **FIGURE 5B** is old and settled science, many studies in recent decades indicate clearly that this much-studied static mechanism is "**de-coupled**" when running, as indicated in the studies cited in **Endnote 10** above.

I was already aware of many of these studies, but I had not specifically addressed the issue in my draft book. I had interpreted the known running decoupling effect to implicitly support a much different conclusion, but I had not explicitly presented my position. My personal thanks to Ned for taking the time to raise this important but unresolved issue so that I can address and emphasize it properly.

Therefore, in response to Ned's concern, I set out to find better support in biomechanics research for my contrary conclusion (and thereby to add to the direct support I have already found in reshaped modern bones and joints, as shown in **FIGURES 9-35** and described in the text). Fortunately, I found excellent support almost immediately in data from the study cited in **Endnote 1** by Steffen **Willwacher**, Irena Goetze, Katina Mira Fischer and Gert-Peter Bruggemann.

The study is titled "The free moment in running and its relation to joint loading and injury risk," in ***Footwear Science*** (2016), Vol. 8, No. 1, pages 1-11 particularly pages **4-9** and **Figures 4-6**. The study is the winner of the **Nike Award for Athletic Footwear Research**, the highest award presented at the **XIIth Footwear Biomechanics Symposium** in Liverpool, UK 2015, a biannual conference sponsored by the **International Society of Biomechanics.**

The Willwacher study provides a large data set of 222 runners, 129 male and 93 female, that I utilized to develop precise mathematical evidence that the artificial shoe heel bio-mechanism is the actual cause of the observed decoupling effect. A summary of the full analysis is below.

Mathematical Explanation of Why Shoe Heel-Induced Foot Supination Is the Cause of Joint Decoupling - Using by Data from the Willwacher Study

In FIGURE 5B, the Rubin study on supination of barefeet found using analogue modeling to illustrate that for every 1° of supination, the tibia is rotated outward (or externally) by about 1.7°, an exact ratio of 1:1.72. This automatic mechanical linkage simulates the biomechanical interaction of biological parts, principally the shin bone, the ankle bone, and the heel bone, as well as the main foot sole ligament (that is, the tibia, talus, and calcaneus, as well as the plantar aponeurosis, and also including the fibula in a minor role).

More precisely, this direct coupling between shoe heel-induced subtalar joint supination and tibial outward rotation is strictly bio-mechanical. It happens automatically. Although biological, the action of the mechanism is as inevitable as if it were a direct mechanical interaction of gears.

It is in fact the closest biological equivalent of a strictly mechanical interaction between parts. Like the automatic mechanical interaction of a large number of relatively simple geometric parts of a clock, the shoe heel bio-mechanism is an automatic interaction of a small number of human bone parts with complex, anthropomorphic shapes.

The **Ankle Angle Frontal Plane** graph of Figure 6 of the Willwacher study shows ankle eversion (effectively identical to pronation) of about **11°** for the average of all 222 runners under a maximum body weight load at midstance while wearing their own mostly conventional running shoes. See adjacent **FIGURE 8F (Selected Willwacher Graphs)**.

According to the Rubin study ratio of 1:1.7, the **11°** of inward rotating **ankle** eversion should be directly coupled with fully **18°** of internal rotation of the tibia (and knee joint).

Instead, in the **Knee Angle Transverse Plane** graph of Figure 6 of the Willwacher study, there is only **8°** of internal rotation of the **tibia (and knee joint)**, fully **10°** less that should be there according to **Rubin's Ratio of 1:1.7**.

The Mysterious Missing 10° of Inward Tibial Rotation

This is a crucial mystery. Why is the **10°** of inward tibial rotation missing? Less than half as much inward tibial rotation occurs in Willwacher's data from running with shoes compared to Rubin's static model of the barefoot without shoes.

The only plausible explanation that exists for this discrepancy is the outward rotation of unnatural supination caused by the artificial structural effect of shoe heels. This **10°** anomaly indicates clear evidence of a very substantial **decoupling** during running in elevated shoe heels of the direct linkage between ankle and tibia rotation found in Rubin's stationary study of barefeet.

In fact, the substantial decoupling shown in the Willwacher study data actually provides clear evidence of the direct mechanical effect of shoe heel-induced supination on knee motion in the transverse plane. His study data thus has been used to establish logically that the shoe heel-induced unnatural supination actually explains the abnormal decoupling. The only other explanation is the current one: decoupling just happens.

The missing 10° of naturally coupled inward tibial rotation is artificially decoupled by an offsetting 10° of shoe heel-induced external tibial rotation resulting directly from (using Rubin's Ratio of 1:1.7) about 6° of shoe heel-induced supination.

That 6° of foot supination is about as expected from unpublished data from the same award-winning study that was recently provided by Dr. Willwacher, wherein the standing position Willwacher's test subjects' feet was on average 4° to 5° of ankle inversion/ supination.*

*This measurement was made while test subjects stood in their own running shoes, which were unidentified but today typically have heels lifts of about **6-12 mm**. Specifically, Dr. Willwacher reported that the static reference angle of ankles **is 4° of ankle inversion (virtually identical to supination) for 129 males** and **5° of ankle inversion for 93 females** – all middle-aged runners measured while standing in their own shoes.

Moreover, Willwacher's **4° of ankle inversion/supination for males** is essentially the same as the **4°** of varus used in 1976 by the eminent podiatrist **Steven Subotnick**, who pioneered the treatment of running injuries at a time when a majority of runners were male. At that time, Dr. Subotnick convinced the **Brooks** Shoe Company to use a **4°** varus wedge in their top-rated Brooks Vantage running shoe to bring the subtalar joint into a neutral position to counteract the functional varus inherent in running. Dr. Subotnick believed that the **4°** varus wedge was appropriate for about two/thirds of all runners (though it is likely more like one/third), particularly those prone to excessive pronation. (See **Cavanagh**, Peter (1080). ***The Running Shoe Book***, pages 81-86, **169-170 (& Fig. 8.5)**, and 335-**336**. Mountain View, CA: Anderson World, Inc. See also **Werd**, Matthew et al. (2017). ***Athletic Footwear and Orthoses in Sports Medicine*** (2nd Edition), page **8**. Switzerland: Springer Nature.)

Dr. Subotnick's foot supination-compensation technology is still in wide usage in many running shoes today, generally in category of shoes the industry calls “stability” or “guidance”. Instead of thickness-varying wedges, today’s equivalent technology has evolved mostly into the form of midsole density variations that are known commercially as medial posts or rollbars, which have the equivalent structural effect under body weight loads of the varus wedges. The technology is so established that at least one such shoe model includes a claim that it may be eligible for Medicare reimbursement.

It should be noted here that Dr. Subotick has been for decades one of the preeminent authorities on the treatment of sports injuries, particularly those of running. He was editor of what has been for many decades effectively one of the “bibles” of sports medicine: ***Sports Medicine of the Lower Extremity*** (2nd Edition, 1999). Philadelphia, Pennsylvania: Churchill Livingstone.

However, in hindsight, Subotick’s varus wedge is counterproductive, since it only reinforces the basic problem, which is the heel lift structure that in causes artificial supination, the instability of which for many runners results in excessive pronation.

The opposite approach, targeted for women, seems to be that developed by **Dr. Casey Kerrigan, MD**, who has formed a successful running shoe company, **OESHshoes**, with a compliant sole technology that dynamically provides a valgus tilt under load so that the artificially supinated foot is repositioned into a neutral, natural alignment. A former collegiate champion runner, her sole design is based on outstanding studies she led at Harvard Medical School that indicated elevated heels increase knee joint torques during walking and running that cause osteoarthritis, particularly for women. However, more recently that technology has apparently been superseded by a 3D-printed flat sole with no heel elevation.

> (See for example **Kerrigan**, D. Casey et al. (2009). The Effect of Running Shoes on Lower Extremity Joint Torques. In *Physical Medicine and Rehabilitation* 1:1058-1063, especially pages **1058-1060** with **Figure 1** and **1061-1062**. See also **Kerrigan**, D. Casey et al. (1998). Women's shoes and knee osteoarthritis. In *The Lancet* 357, April 7, **1097-1098**, particularly **both pages**.)

Summarizing our conclusion based on Willwacher’s data and Subotnick’s extensive real-world experience, a natural **in**ward tibia rotation of **10°** is cancelled out by an unnatural **out**ward tibial rotation in the opposite direction of **10°** that is caused artificially by **6°** of shoe heel-induced foot supination. The remaining **observed net** inward tibia rotation becomes only **8°** because of shoe heel-induced foot supination for common running shoes when running in shoes.

The calculated result of **6°** of shoe heel-induced foot supination for common running shoes is the most accurate we can get for now. No studies currently exist that have measured unloaded foot supination with running shoes of varying heel heights in the midstance running position of the ankle joint.

The results of many well-established studies, moreover, have indicated that the unloaded landing position of the shod foot when running have a general range of **0°** to **10° supination**, with a sample average that includes about **6°** (Hamill, Gruber and Miller), about **2°** (Willwacher), and about **8°** (Cavanagh). Therefore, the above calculated result of about **6°** of shoe heel-induced foot supination for common running shoes with heel lifts of about **6-12 mm** is reasonable.

> **(**Willwacher's test subjects, moreover, are probably outliers, since they are middle-aged "survivor" runners, not typical runners and not at all typical representatives of the human population. Their foot (and leg) positions therefore are probably closer to neutral, meaning vertical, than is the norm. His atypical test subjects make it reasonable to discount his low **2°** result in favor of something closer to the higher **6°** result that we computed from the data. Furthermore, Willwacher's measurement of **4-5°** noted above was taken at rest and therefore may be more accurate.
>
> **Cavanagh**, Peter R. (1987). The Biomechanics of Lower Extremity Action In Distance Running. In ***Foot & Ankle*** 7: 4: 197-217, particularly pages **197**, **200-201**, **207 & Figure 11**, **210-211 & Figure 15** and **213-215 & Figure 16**. See also **Cavanagh**, Peter R. (1982). The shoe-ground interface in running. In ***Symposium on the Foot and Leg in Running*** **Sports** (Mack, Robert P. Ed.). St. Louis: The C.V. Mosby 30-44, particularly pages **33-34** with **Figure 2-3**. Edington, Christopher; Frederick, E.C.; and Cavanagh, Peter (1990). Rearfoot Motion in Distance Running. In ***The Biomechanics of Distance Running.*** Cavanagh, Peter (Editor) Champaign, IL: Human Kinetics Books, pages 141-144 and **Table 5.1**.
>
> **Hamill**, Joseph**, Gruber**, Allison and **Miller**, Ross (2013). Footwear Effects on Running Kinematics, **pages 459** and **464-7** with **Figures 21.7 & 21.10** [Note: I used the supination angle given for rearfoot strikers (RF), the most typical runners wearing conventional elevated heel running shoes]. From **Goonetilleke**, Ravindra (2013). ***The Science of Footwear***. Boca Raton, FL: CRC Press.**)**

The observed **11°** of foot eversion (or pronation) is therefore a **net composite** of what must actually consist of about **5°** natural eversion from a neutral, vertical alignment and about **6°** of additional, unnatural eversion that compensates directly for the about **6°** of artificial shoe heel-induced inversion (or supination).

In other words, the foot has to evert inward about **6°** in order to get to a neutral, vertical alignment from an unnatural **6°** inversion position caused by the shoe heel bio-mechanism. Incredibly, then, the majority of ankle joint inversion (or pronation) during running observed by Willwacher is apparently abnormal motion required just to move the foot to a more natural, vertical position.

The easiest way to understand this odd result is that the runner's foot is pronating to an excessive, abnormal degree to compensate for the artificial structural effect of the elevated shoe heel, which has unnaturally rotated the foot outward into an abnormal supination

position.

This final result – based on extensive data from Willwacher's celebrated study - explains mathematically the existence of a direct bio-mechanical decoupling effect of shoe heel-induced ankle joint supination and its directly caused artificial tibial external rotation. His study data is especially authoritative because of its exceptionally large and therefore more statistically valid sample size (222 runners) compared to nearly all other running studies, which are of much smaller size!

The Basic Problem with the Classic Running Studies on the Subtalar Joint Axis

When I reviewed all the joint coupling running studies cited above in **Endnote 10**, I noticed that they neither cite nor referred to Gustav Rubin's static study. For example, the Stacoff study assumes "a theoretical **1:1** coupling from the calcaneus to the tibia" relative to its Figures 4 & 5, whereas Rubin's Ratio is **1:1.72**. That is, Rubin's ratio is nearly **1:2**, not **1:1**.

The Stacoff empirical result during running was **1.72**, or nearly two degrees of ankle **eversion** for every one degree of internal tibial rotation. This is exactly the opposite of Rubin's stationary result of nearly two degrees of tibial rotation for every one degree of foot **supination** (pronation/ supination is nearly the same as rearfoot eversion/inversion). I believe his results are misleading because they simply do not account for the decoupling effect of shoe heels.

The DeLeo. study cites the results from all the relevant joint coupling running studies (through 2004) and all have similar ratios showing more or substantially more ankle eversion than tibial rotation during running. These results are also roughly the polar opposite of Rubin's result, but again do not account for the decoupling effect of shoe heels.

The results summarized by DeLeo vary widely, from **1.0** to **2.2**, because ankle joint coupling is difficult to measure accurately for subjects who are running. In marked contrast, it is easy to develop accurate analogue models for subjects who are stationary. Consequently, it is difficult to ignore Rubin's results.

Other Problems with the Classic Studies on the Subtalar Joint Axis

The decoupling studies cited in **Endnote 10** mostly use a simple assumption of a **1:1** ratio of motion between calcaneus and tibia, based on an assumed **equidistant 45°** inclination angle for the subtalar joint axis in the sagittal plane found in the **Root** et al. study of cadaver feet.

In contrast, Rubin used a slightly lower **41°** inclination angle, but more significantly also used a **23°** angle (offset medially) in the transverse or horizontal plane to construct an analogue model (Verne **Inman** did not use this offset adjustment in the earlier analogue modeling he described in his classic text, ***The Joints of the Ankle***. The Williams & Wilkins Company: Baltimore, 1976)

Even if we do not consider Rubin's work, the Root assumption of **45°** is questionable, since an actual study of a small number of living test subjects by A. **Lundberg** found a mean subtalar joint inclination angle of **32°** rather than **45°**. See "Kinematics of the ankle and foot". ***Acta Orthop Scand Suppl*** **60**: 1, 1989. (See also an excellent discussion of the assumption issue by Irene McClay (Davis) in "The Evolution of the Study of the Mechanics of Running" (2000) in the ***Journal of the American Podiatric Medical Association*** **90**: 3: 133-148, especially **page 144**, column 1.)

The Root study was conducted on freshly amputated feet that had been dissected to bone and ligament alone. This distinction may be significant. The dissected feet of Root were unloaded, whereas Lundberg's living feet studies presumably were loaded by roughly half of the body weight of test subjects. Furthermore, a later study by E.J. **Van Langelaan** on loaded cadaver feet had results close to Rubin's joint axis angles, as disclosed in "A kinematical analysis of the tarsal bones." ***Acta Orthop Scand Suppl***. 1983: 204:1-269.

Much Better Rearfoot Measurement Parameters Have Been Demonstrated

Cited in **Endnotes 9 & 10**, Katrina Mira **Fischer** has conducted the latest and possibly best running decoupling study. Fischer's study strongly suggests that rearfoot motion in the horizontal (transverse) plane provides a more accurate basis for measuring the coupling of foot and lower leg motion during running than rearfoot motion in the frontal plane (the vertical plane showing right and left sides). In other words, calcaneal adduction rather than calcaneal eversion, as shown in her **Figure 1** on **page 88**, is strongly coupled with tibial rotation.

Fischer's barefoot running demonstrates results of an observed average of **7.8°** of calcaneal adduction for an average of **12.1°** of internal tibial rotation - an average **Fischer running coupling ratio** of calcaneal to tibial motion of **1:1.55** (1.73, 1.72 & 1.41 for individual subjects).

Fischer's running coupling ratio of **1:1.55** is nearly the same as the **Rubin static coupling ratio of 1:1.72** cited in **Endnote 9** and illustrated in **FIGURE 5B.** Because Rubin's study measured foot supination and pronation, the similar results between the running and static ratios suggests that the measurement of calcaneal adduction tracks foot supination and pronation more accurately than does the measurement of calcaneal eversion.

> See Katrina Mira **Fischer**, Steffen Willwacher, Anton Arndt, Peter Wolf and Gert-Peter Brueggemann (2017). Calcaneal adduction in slow running: three case studies using intracortical pins. ***Footwear Science***, Vol. 9, no. 2, 87-93, particularly **Figure 1, page 88,** and **Table 1, page 90**.

All of the Ankle Joint Coupling Studies Have Serious Shortcomings

The earlier studies on the coupling of foot pronation/internal tibia rotation do not account for many important factors that are unique to running. For example, the load on the foot and ankle joint in running is two to three times greater than a loaded cadaver foot with a simulated walking load of a body weight. Also, at room temperature cadaver feet are much colder and less flexible than living feet.

Both factors significantly depress the longitudinal arch height of the living foot when running compared to tested cadaver feet. In running feet, the subtalar joint axis will likely be lowered in the sagittal plane well below **45°** (or Lundberg's **32°)** and rotated further to the medial (or inside) in the horizontal plane.   (Many published studies on the drop of the main longitudinal arch of the foot under load demonstrate this result by showing the lowered position of the navicular bone).

All the existing studies, moreover, assume a vertical tibia, whereas at midstance in running the tibia is tilted forwarded about **25°** in dorsiflexion. In addition, the ankle joint itself is angled downward on the medial side in this maximally **25°** dorsiflexed ankle position. None of the previous studies include either of these important factors.

To these shortcomings must be added a more significant one. Although the average angle of inclination assumed in the **Endnote 10** studies was 45°, the actual range was from an angle of almost 70° for the highest arched (or cavus) foot to only about 20° for the lowest arched (or planus) or flat foot.

Can any average with that great a range provide meaningful results for individual runners? At the least, we must establish average angles in inclination for categories of runners, such as normal runners, pronating runners, and supinating runners. Only the measurements of each individual runner can provide a truly accurate biomechanical approach.

The huge **50°** range of inclination angles for the subtalar joint strongly suggests that each runner's individual structural reaction to the effect of shoe heel-induced supination on the bones of the runner's ankle joint complex determines each runner's individual inclination angle.

Elevated Shoe Heels Have Greater Effect on Higher Main Longitudinal Arch Feet and Less on Lower Main Arch Feet

The bottom line relative to inclination angles of the subtalar joint in the sagittal plane is as follows. Individuals whose supinated feet demonstrate higher longitudinal arches have inclination angles that are greater than **45°** and greater tibial rotation for each degree of pronation or supination during running.

Individuals whose pronated feet demonstrate lower arches have inclination angles that are less than **45°** and less tibial rotation for each degree of pronation or supination. (These relationships were noted by Benno **Nigg** et al. (1993). Effects of arch height of the foot on angular motion of the lower extremities in running. In the ***Journal of Biomechanics*** 26: 8: pages 909-916.)

This point is critical. Shoe heels generally have a more extreme effect on individuals with feet that are more supinated and with higher arches. Their tibias, for example, will

externally rotate farther during running, and this unnatural rotation will increase the abnormal rotary structure of the modern knee shown in FIGURE 9A.

In contrast, shoe heels typically have a less extreme effect on individuals with feet that are more pronated and with lower arches. Their tibia will externally rotate less during running, and this more natural rotation will allow their knees to have the more natural, less non-rotary structure demonstrated in the natural barefoot knee shown in FIGURE 9B.

The change in the inclination angle of the subtalar joint is due to a physical change in the position of the subtalar joint (between the ground-contacting calcaneus base and the pivoting talus). Higher arched individuals with supinated feet have a calcaneus in a position that is higher and rotated laterally, while lower arched individuals with pronated feet have a calcaneus in a position that is lower and rotated medially.

The Classical Physics Approach Has Been Lost in the Technical Complexity

The classic physics of Galileo and Newton was built on a foundation using the simplest experiments possible in order to test the effects of gravity alone, with other effects excluded. That simplicity made it possible for those pioneers to see through the fog of real-world complexity, providing them with a clear foundation on which to build a general gravitational theory. Secondary factors like air friction, wind, temperature, and humidity are added in later to get results that match the real world.

For example, Galileo used an inclined plane to study gravity without air resistance and with reduced speed to make accurate measurement possible of the acceleration caused by gravity. Newton observed a falling apple from a tree and saw it as a simple model of the gravitational force of attraction between planets.

The existing approach in biomechanics studies to the decoupling anomaly, in contrast, proceeds as if the Galileo and Newton had tried to understand gravity by first studying the actual flight of cannon balls. If they had chosen this difficult and dangerous approach, gravity might still be a mystery today.

If biomechanics as a science were instead to follow this classic approach, an accurate ankle joint coupling ratio derived from living subjects while stationary would be the simple case forming a good theoretical baseline, against which actual running results should be measured. Any difference in the real-world running results must be explained in explicit terms of how and why a ratio accurately derived from stationary living test subjects is altered when running.

In contrast, without an accurate consensus stationary baseline against which to measure, all actual running test results tend to become a confusing jumble of data noise. Just such a jumble has been the case until now in the study of human ankle joint decoupling.

Therefore, in meaningful running research, the difference in level of forces and motions between stationary and running measurements must be accounted for as the principal natural difference from an accurate consensus stationary baseline. The principal artificial difference is both the geometric structure and deformation characteristics of shoe soles and elevated shoe heels, which also must be accounted for in order to accurately obtain meaningful results.

Both differences must be evaluated in empirical running studies against an accurate consensus stationary baseline to obtain scientifically valid results.

Dr. Frederick's General Reaction to the Above Decoupling Analysis

As noted in the text, Dr. Frederick had no specific objections to the above analysis. He did however voice one principal remaining concern, which was that individual variation seemed to be so great that it would be difficult to develop meaningful general solutions to the problems I have indicated (hopefully this paraphrases his comment accurately).

To this I would respond that I agree, but that this wildly excessive individual variation is in fact the most general effect of elevated shoe heels. The best specific example of this general effect is the knee. The knee is forced during running out of a state of natural equilibrium between opposing forces into an unstable state causing in direct compensation an unnaturally wide range of individual variations, as discussed relative to **FIGURES 8A&B**.

Data from the Willwacher study (graph on **Knee Angles in Frontal Plane** – shown above in **FIGURE 8F**) – demonstrates the extraordinarily high (if not wildly excessive) individual range of variation of knee abduction/adduction motion between the 222 runners, as expected given each individual's specific genetic adaptation to their own particular, highly variable shoe heel use.

The frontal plane knee motion shown in **FIGURE 8F** is, by far, the most erratically variable of all the lower limb joint motions measured in the Willwacher study. This unusually erratic variability suggests that individual employ wide individual variation when they compensate for the lateral instability in the modern knee joint caused by the unnatural effect of elevated shoe heels.

Without the artificial effect of elevated shoe heels, knee motion would be much more consistent between individuals, sexes, and genetic backgrounds. As would all other joint motions and structures. Unfortunately, shoe heel-induced supination forcibly creates an artificial preferred path of joint motion with an abnormally large range of variation.

Dr. Frederick's Other Major Misgiving About Heel Height Studies Like Mine

Besides his concern regarding ankle joint decoupling that I have already discussed above, Dr. Ned Frederick had another noteworthy comment on my book's early first draft. It is that there currently is no generally accepted industry standard or protocol for measurement of elevated shoe heels.

Dr. Frederick is certainly correct that the shoe industry has failed to establish consistent criteria for the measurement of heel height in the industry (either by footwear or last makers) or in the scientific studies of its footwear products. For that matter, heel height is rarely measured at all in most running studies. Those failures are a serious problem that needs resolution. My hope is this article (and book) will provide a powerful and long-needed impetus for real progress finally in that effort within the industry.

Nevertheless, it is a simple matter to measure the essential structural difference in any footwear between the heel area and the forefoot area in a gross but meaningful way, even if less than perfectly consistent.

That is already being done quite often today, despite the needless confusion that results when we call the resulting measurement values "heel lift," "heel offset," "heel drop," or "pitch," "gradient," or "stack" (all terms commonly used today meaning approximately the same thing, which I have referred to with the term "elevated shoe heels"). Clearly, comparing heel heights as done today is not be perfectly accurate or consistent, but it is easy to do and still highly useful for comparison.

But Dr. Frederick also takes the surprising position that heel height must be measured during running at instants of maximum deformation in order to generate meaningful research results. As with static measurement, however, there is no established protocol for dynamic measurement nor consensus for it, nor does Dr. Frederick suggest any. The only thing certain about the proposed measurement during running requirement it that it would be difficult to achieve accurate results, if not practically impossible today, and, of course, both expensive and time consuming in the extreme.

I firmly believe that static measures of heel height are without reasonable doubt good enough for meaningful biomechanical test results. Without any doubt, it is the best first step.

On a more fundamental level, no potential benefit of dynamic measurement of heel height compared to static measurement is identified. Nor, more practically, has any case been made that the increased cost and significant delay would be justified. In addition, no references are cited upon which the requirement for dynamic heel height measurement might be based.

The closest and best analogy I can think of is this: although the side-to-side frontal plane thickness and deformation of footwear soles seems at least equally relevant in the study of running pronation and supination, no such roughly equivalent capability currently exists to measure dynamic lateral and medial compression of footwear soles. Certainly, no published research studies contain any such data.

Nevertheless, despite that absence, there are a massive volume of existing biomechanical running studies that profess to provide meaningful results concerning pronation and supination. That raises a logical question: why has it never been important to measure shoe soles dynamically in the frontal plane during running in order to measure pronation and supination, but is fundamentally important now in the sagittal plane to measure shoe heel height during running?

An Update: Dr. Frederick's recent reaction to the foregoing comments by me was constructive and in two parts. First, he believes that dynamic measurement of heel lift is likely to be easier to do than I thought and is therefore potentially more practical in the near term.

Second, he believes that the results of dynamically tracking heel lift during running is likely to demonstrate an increase in effective heel height in the later stages of the ground support phase of running, potentially increasing the biomechanical effect of elevated heels on the human body.

"Form Follows Function" is Largely Ignored in Running Biomechanics Research

More to the point, unanswered is the question of why it is also not important to at least measure shoe soles statically in the frontal plane prior to studying pronation and supination during running. Footwear sole structures vary widely in thickness, material density, width, and shape in the frontal plane, and they typically vary from one frontal plane section to another, and do so many times throughout the length of the sole. Yet these variations are almost never accounted for in any way in peer reviewed studies, and never in rigorous detail.

The structure of footwear soles is a critical but unknown and totally random variable in running biomechanics research, even in its simplest and easiest measured form: that is, statically. Does that mean that all existing running biomechanics studies are so insufficiently complete that they cannot produce reliable conclusions?

"Form follows function" is a truism in functional design, but the actual shoe sole form – that is, structure – is usually ignored in running biomechanics studies. The majority of such studies do not even mention the specific shoe model or models used in the study. None specify the actual structure of the shoe soles in detail, which is the actual physical structure directly supporting the running foot being studied.

Nor, for that matter, is the actual structure of the wearer's foot or shape of the wearer's foot sole ever typically measured in any way in these studies, even for basic size, much less for the foot sole's overall shape or its bone and joint structure.

Nor is the wearer's foot structure ever correlated in any way with corresponding shoe sole structure, even for basic fit, but much less for the dynamic interaction between the two during running. If any shoe companies do research on any of these issues, their results remain secret.

An Unusually Large Sample Size, But Highly Selected Instead of Random

I now wish to return to the outstanding Willwacher study that I discussed at the beginning of this endnote. To its credit, the study's sample size is much larger than a typical biomechanics study, and it includes both men and women.

I must unfortunately also note, however, that the runners studied are all middle-aged. This means that on a de facto basis the subjects are highly selected biomechanically, since it is likely that most of them apparently have remained runners after surviving many years of annual injury rates that reach as high as 70% in the active running population.

The study, moreover, limited its runners to those who had been injury-free for at least the past six months. This good health renders them very unique indeed, again given the typical 70% annual injury rates.

The study, in short, failed to randomly select its test subjects. The subjects did not reflect the overall population, even within their age group. The study instead selected highly filtered, elite winners who had triumphed in a lifelong "survival of the fittest" race in an age group in which nearly all other runners are former runners.

A truly random study of subjects in this age group would likely include only a small number of active runners among all the subjects to be studied randomly. That is, of course, why this study and all other running studies are never randomized and therefore cannot at all represent the overall human population.

This problem is serious. Without random test subjects, no existing biomechanical studies on running examine the effects of elevated shoe heels on the general human population.

It is expected that these effects are generally more adverse – with much greater abnormal distortion of joint motion and skeletal structure – in the general population than the relatively elite runners invariably used as test subjects.

On the positive side, the unique older runners in the Willwacher study do provide a rational guide to interpreting the its results. It is reasonable to conclude that the middle-aged runners' relatively straight-to-slightly-valgus legs enabled them to avoid injury and continue running far longer that typical of active runners.

Willwacher's data shows the knee torqued into an unnatural varus position. Long-term runners with few injuries have bodies that seem to compensate, however, with a moderate foot pronation that offsets the abnormal knee torque caused by shoe heels. World class champions demonstrate the same relatively straight-to-slightly-valgus legs.

A quick trip around any shopping mall, however, will convince you that the overall population does not enjoy this structural advantage. A large portion of the males are significantly bowlegged when walking, and a similar portion of the females are significantly knock-kneed, as I have discussed in detail earlier.

An important further note: like all running biomechanical studies, the Willwacher study tests and provides results for only one leg, the right, and ignores the other leg on the assumption that both legs are the same. This assumption is almost universally accepted in human running studies.

That convenient assumption, however, has now been proven wrong definitively. We now know generally, instead, that the right and left legs are in fact asymmetrical in form and function (see **Endnote 12** below).

Of course, it is easy to understand why most studies have been limited to only one leg: it is difficult enough to evaluate all the data points needed from just one leg in order to adequately measure its function. To assess both legs, and then correlate the differences between them - while also correlating those leg differences with data points from other parts of the body – is a herculean task.

As wearable, wireless electronic technology evolves, that complexity problem will become much easier to solve. Historically, though, the complexity has been overwhelming and too costly.

A Fundamental Breakdown in Biomedical and Biomechanical Research

Finally, a section-leading article with the above title appeared recently in ***The Wall Street Journal*** (April 7, 2017). Among many other very troubling studies, it refers to a study titled "Why Most Published Research Findings Are False," (***PLOS Medicine***, August 30, 2005) by John Ioannidis, an epidemiologist and health-policy researcher at Stanford University.

The article notes that, unlike drug studies involving humans, "The problem is especially acute in laboratory studies with animals, in which scientists often *just use a few animals and fail to select them randomly*" (italics added).

Human biomechanical studies on running in shoes encounter the same problem: the animals are human Guinea Pigs, who have not been selected randomly from the general population. The studies ignore the non-active runners who comprise the vast majority of the general population, and this omission renders their results inherently suspect and potentially misleading.

The biomechanical effects of shoes that have made non-runners out of most of the human population, despite evidence that they were born to run, are completely unresearched and therefore unknown.

For more on the validity problem in modern research, see also Randall, David and Welser, Christopher (2018). **The Irreproducibility Crisis of Modern Science**, National Association of Scholars. April, 2018. www.nas.org/images/documents/NAS_irreproducibilityReport.pdf

12A. **Reinschmidt**, C., van Den Bogart, A. J., Murphy, N., Lundberg, A., and Nigg, B. M. (1997). Tibiocalcaneal motion during running, measured with external and bone markers. ***Clinical Biomechanics***, 12 (1), 8-16.

12B. **Arndt**, A., Wolf, P., Lui, A., Nester, C., Stacoff, A., Jones, R., Lundgren, P. and Lundberg, A. (2007). Intrinsic foot kinematics measured in vivo during the stance phase of slow running. ***Journal of Biomechanics***, 40, 2672-2678.

12C. **Bey**, M. J., Peltz, C. D., Ciarelli, K., Kline, S. K., Divine, G. W., van Holsbeeck, M. ... Moutzouros, V. (2011). In vivo shoulder function after surgical repair of a torn rotator cuff: glenohumeral joint mechanics, shoulder strength, clinical outcomes, and their interaction. ***American Journal of Sports Medicine*** 39 (10), 2117-2129.

12D. **Peltz**, C. D., Hakadik, J. A., Hoffman, S. E., McDonald, M., Ramo, N. L., Divine, G., Nurse, M. and Bey, M. J. (2014). Effects of footwear on three-dimensional tibiotalar and subtalar joint motion during running. ***Journal of Biomechanics*** 47, 2647-2653. (Figs. 4, 7 & 8)

13. Many Research Studies Have Experimentally Confirmed the Twisting Effect of Elevated Shoe Heels on Ankle Joints and Foot

A relatively recent study in 2012 by Danielle **Barkema**, Timothy Derrick, and Philip Martin experimentally confirmed the existence of this artificial supination effect of shoe heels on the ankle joints and foot. Specifically, in an experiment with 15 women, they found as follows:

> **As heel height increased** for both fixed and preferred [walking] speeds, rearfoot angle became more positive throughout stance, i.e. the center of the ankle joint shifted laterally relative to the heel point of contact, which contributes to **an inversion-biased ankle orientation** (Fig. 4). (Emphasis added)

See **Barkema**, Danielle D. et al. (2012). Heel height affects lower extremity frontal plane joint moments during walking. In ***Gait & Posture*** 35: 483-488, particularly pages 483, 485-487 with Figures 2 & 4. See also Cronin, Neil J. (2014). The effects of high heeled shoes on female gait: A Review. In the ***Journal of Electromyography and Kinesiology*** 24: 258-263. particularly pages 258 and 261.

Another walking study, also in 2012, by Alicia **Foster**, Mark Blanchette, Yi-Chen Chou, and Christopher Powers indicated an increase from low heels (1.3 cm or ½ inch) to high heels (9.5 cm or 3½ inches) coincides with a peak ankle inversion angle increase from 3 degrees to 9 degrees. The high heels take the foot to near maximum supination, since reports indicate that fewer than 8 degrees are about the maximum passive range of motion for inversion.

See **Foster**, Alicia et al. (2012). The Influence of Heel Height on Frontal Plane Ankle Biomechanics: Implications for Lateral Ankle Sprains. In ***Foot & Ankle International*** 33: 64-69, particularly pages 64, **67 with Table 1** and **Figure 3B**, and 68.

In an earlier study in 2000 with 37 women, Makiko **Kouchi** and Emiko Tsutsumi also found that as the height of a shoe heel increases, the foot supinates; a study with 13 women in the same year by Darren **Stefanyshyn** and others reached the same conclusion.

See **Kouchi**, Makiko & Tsutsumi, Emiko (2000). 3D Foot Shape and Shoe Heel Height. In ***Anthropological Science*** 108: 4: 331-343, particularly page **331**, 336-338 with **Figures 5-7**, and **342**. **Stefanyshyn** et al. (2000), The Influence of High Heeled Shoes on Kinematics, Kinetics, and Muscle EMG of Normal Female Gait. In the ***Journal of Applied Biomechanics***

16: 309-319, particularly pages 309, 313-316. See also **Hong**, Wei-Hsien et al. (2013). Effect of Shoe Heel Height and Total-Contact Insert on Muscle Loading and Foot Stability While Walking. In ***Foot & Ankle International*** 34: 2: 273-281, particularly pages **273**-274, 276-**277** with **Figure 3(b**), and 279 with Figure 5.

In addition, a 2002 study by Timothy **Derrick**, Darrin Dereu, and Scott McLean indicated that **the foot becomes more inverted at impact at the end of an exhaustive run in conventional running shoes, demonstrating a direct cause and increasing effect**, even in a relatively short period of time.

See **Derrick**, Timothy R. et al. (2002). Impacts and kinematic adjustments during an exhaustive run. In ***Medicine and Science in Sports and Exercise*** 998-1002, particularly pages **998** and 1000-**1001 with Table 2**. See also **Clarke,** T. E. et al. (1983). The effects of shoe design parameters on rearfoot control in running. In ***Medicine and Science in Sports and Exercise*** 15: 5: 376-381, particularly page **377 with Fig. 1**.

14. The figures are 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, particularly **Figure 2 on page 139** and from **PBS NOVA** (2014) "*Roman Catacomb Mystery*."

The few examples of "barefoot" knees listed in the text are the only photographic evidence publically available that I have been able to find. I should note that <u>none</u> of the evidence that I have included in this article is intentionally "cherry-picked," although it might appear to be, since the available evidence is so limited and very spotty. I have used these images simply because they are all there is publically available, despite my extensive efforts to find more.

In fact, the shortage of useable evidence has motivated my decision to publish my preliminary findings now, despite their unfinished form. Additional evidence certainly exists all over the world, but it is not publically available.

For example, a multitude of very old Caucasian tibia exist throughout Europe that could provide a good indication of the actual structure of European "barefoot" Caucasian knees (the footwear in use at the time – especially in Northern climates – of course remains unknown.) Additional unequivocal evidence may be available from modern Caucasians who have grown up and lived continuously without footwear in South Pacific islands.

In the interests of full disclosure, I have found only one item which indicates contrary evidence. I consider the evidence weak, but it is as follows: the tibia of an apparent family of British Neolithic humans (from around 10,000 A.D., about the time that agriculture developed) had an unusually elongated medial condyle.

There is no indication, however, of rotary motion such as that found in the modern European tibia shown in **FIGURE 9A**. There is also evidence of use of unknown footwear. See Figure 25 on page 177 of ***The Skeleton of British Neolithic Man*** by John **Cameron** (1934). London:

William & Norgate Ltd.: London.

15. The rotational motion in the horizontal plane during the stance phase in running is substantial and irregular: initially internal **1º**, then external **1º**, then internal **8º**, and then external **9°**. The individual range of variation between the 222 runners in the study is very high, as expected given each individual's specific genetic adaptation to their own particular, highly variable shoe heel use. Graphical data from the same source on knee angles in the frontal plane is even more erratic during stance, with **1º** a**b**duction, then **1º** a**d**duction, then **3º** a**b**duction, and then **2º** a**d**duction.

15A. See David **Schmitt** et al. (2008). Why Can't a Man Be More Like a Woman? Sex Differences in Big Five Personality Traits Across 55 Cultures. In the ***Journal of Personality and Sexual Psychology*** Vol. 94, No. 1, 168-182.

16. Dr. Willwacher has generously provided unpublished additional data from his study[11] indicating about **14°** of inward tilt or right hip adduction for 129 **males**. That degree is even higher than the less precisely measured 10 degrees for the individual male illustrated above in **FIGURE 17B**. For 93 **females**, the right hip adduction is exceptionally high at **17°**.

16A. **Gardner**, Adrian et al. (2017). What is the variability in shoulder, axillae and waist position in a group of adolescents? In ***Journal of Anatomy*** 231: 2: 221-228. **Akel**, I. et al. (2008). Evaluation of shoulder balance in the normal adolescent population and its correlation with radiological parameters. ***Eur Spine J*** 17:348-354.

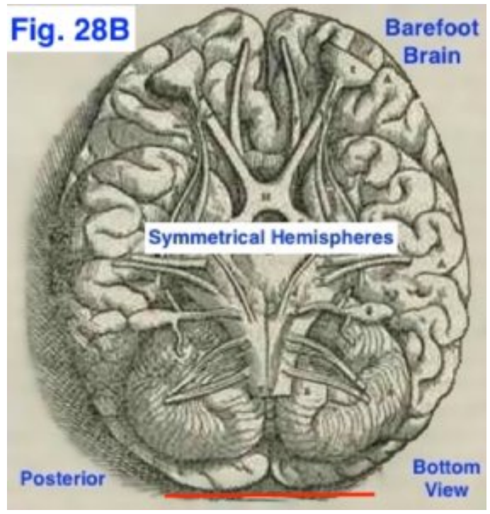
16B. **Lambach**, Rebecca L. (2014). Evidence of Joint Moment Asymmetry in Healthy Populations during Gait. In ***Gait Posture*** 40(4): 526-531

17. See Adam **Rutherford** (2017). ***A Brief History of Everyone Who Ever Lived***. The Experiment. **Rohde**, Douglas et al. (2004). Modelling the recent common ancestry of all living humans. In ***Nature*** 431, 562-566 (September 30). Peter **Ralph** & Graham **Coop** (2013). The Geography of Recent Ancestry across Europe. In ***PLOS:Biology*** https://doi.org/10.1371/journal.pbio.1001555.

18. For the latest among many past studies with similar results, see **Song**, Jinsup et al. (2018). Comprehensive biomechanical characterization of feet in USMA cadets: Comparison across race, gender, arch flexibility, and foot types. In **Gait & Posture** 60: 175-180, February.

19. **Silva**, Rodrigo S. et al. (2017). Effects of Altering Trunk Position during Landings on Patellar Tendon Force and Pain. In ***Medicine & Science in Sports & Exercise*** 49: 12: 2517-2527.

20. **Gazzaniga**, Michael S. et al. (2014). ***Cognitive Neuroscience: The Biology of the Mind (4th Ed.).*** New York: W. W. Norton & Company. The torsional-shift anatomical asymmetries between the right and left hemispheres are shown in a bottom view, from Figure 4.5, page 126.



21. In contrast to the modern brain shown in **FIGURE 28A**, **FIGURE 28B** is a drawing, from 1543 by Andreas **Vesalius**, which shows a bottom view of a **pre-modern, natural brain** that developed before the general use of elevated shoe heels*. Unlike the modern human brain, Vesalius' drawing shows a natural barefoot brain with symmetrical hemispheres with no major shifting or rotary torsion, just a tiny, opposite shift forward of the left hemisphere, not the right.

Vesalius**, Andreas (1543). ***De Humani Corporis Fabrica Libri Septem, Basel, the Base of the Brain. From Wikipedia Commons. See also **Saunders**, JB de CM. and O'Malley, Charles D. (1973). ***The illustrations from the works of Andreas Vesalius of Brussels***. New York: Dover.

A neuroanatomy book published in 1664 by Thomas Willis, an Englishman who is considered the founder of modern clinical neuroscience and comparative neuroanatomy*, give us the most detailed early drawing of the human brain. That drawing is included here as **FIGURE 28C** (and, interestingly, it is attributed to **Christopher Wren**, the celebrated architect who designed London's Saint Paul's Cathedral).

The Wren drawing shows a **bottom view** of the base of a human brain, and Wren, of course, completed the drawing at a time when elevated shoe heels were not in common use. So, like **FIGURE 28B**, **FIGURE 28C** shows a presumably **pre-modern, natural brain**.

Sandrig**, Susan (2016). A brief history of topographical anatomy. In ***Journal of Anatomy 229: 32-62. The first figure in Thomas Willis' ***Cerebri Anatome*** (**1664**), from the President and Council of the Royal College of Surgeons of England. **Arraez-Aybar**, Luis-Alfonso et al. (2015). Thomas Willis, a pioneer in translational research in anatomy (on the 350th anniversary of ***Cerebri anatome***). In ***Journal of Anatomy*** 226: 289-300.

Unlike the modern human brain, the Wren brain drawing shows no forward shift of the right hemisphere. Instead, it shows a very slight forward shift of the opposite hemisphere, the left hemisphere. If the Wren brain reflects any rotary torque at all, it is minor and in the opposite direction from that shown in the modern brain.

This small left-side-shift-forward asymmetry of the Wren drawing may simply reflect the prevalence of right handedness in humans, since the left hemisphere of the brain controls the right side of the human body. If so, then the evolutionary development of human bipedalism, which enabled the development of tool and weapon use, predominately in the right hand and arm, may have led to an initial, partial stage in human asymmetry, but in the opposite direction as the asymmetrical structural development of the modern human brain.

FIGURE 28D shows the earliest (1844) detailed drawing of a **top view** of a human brain, by A. L. F. Foville, a French physican*. Unlike the modern brain, **Foville**'s drawing shows a presumably **pre-modern, natural brain** with symmetrical hemispheres with no significant shifting and indication of rotary torque, except a minor left shift like the Wren drawing, which, again, is in the opposite direction of the modern brain right shift.

> ***Sandrig**, Susan (2016). A brief history of topographical anatomy. In ***Journal of Anatomy*** 229: 32-62. Plate 11 in Achille Louis Foville's Atlas published with ***Traite complet de l'anatomie, de la physiologie et de la pathologie du system nerveux cerebro-spinal*** (**1844**), from the President and Council of the Royal College of Surgeons of England.

Of course, we cannot know whether that brain is truly a "barefoot" brain reflecting the absence of elevated shoe heel use. After the French Revolution of 1789, however, elevated heel use fell into an extended period of general disfavor, since the elevated heel was stylistically emblematic of the excesses of the corrupt French nobility. During this period, moreover, most dissections were performed on bodies from the lowest classes, and these bodies, of course, were the least likely to have ever worn shoes with stylish elevated heels.

Unfortunately, the very small sample of drawings of the pre-modern, natural human brain are the only evidence of its structure available in published literature. The span of nearly two centuries between the Wren drawing of 1664 (other than that of Vesalius of 1543, the first relatively detailed drawing of the human brain) and the Foville Drawing of 1844, moreover, speaks volumes about how little detailed brain anatomical evidence exists in the public record before the 20th Century.

Albert Einstein's Asymmetrical and Brilliant Brain

At least in some individuals, the possibility exists that this unnatural twisted asymmetrical structure of the the modern brain inadvertently enhanced its highest level of mental functions, language and logic. The evidence suggests that the asymmetrical brain change includes an important increase in the size of the **left hemisphere's dorsolateral prefrontal cortex**, the specific part of the brain that handles its most complex mental functions.

The brain of Albert Einstein provides an extraordinary example of the possible value of brain bilateral asymmetry. As shown in a top view in **FIGURE 28E**, **Einstein's brain was bilaterally asymmetrical**, with unnatural counterclockwise rotary torque squeezing the right hemisphere forward and compressing it relative to the wider left hemisphere (in yellow).

The left hemisphere has expanded into a greater maximum diameter (crossing over brain centerline), allowing for an increase in size of the left hemisphere's critical dorsolateral prefrontal cortex – again, the location of the brain's highest intellectual functions.

Of course, the accuracy of any of the previously referenced centuries-old brain drawings remains unknown. However, Einstein's modern brain is carefully drawn from the published photograph shown in **FIGURE 28E'** and is highly accurate. As is clear in the photograph, even component parts of his brain (in yellow) are substantially shifted between right and left hemispheres.

However, unlike the Einstein brain, there are no conclusive photographic or physical anatomical evidence for the pre-modern, natural brain. Therefore, the definitive anatomical structure of the pre-modern, natural human brain remains uncertain.

However, modern technology, however, including MRI and other scanning techniques, as well as standard gross anatomy lab techniques, could be easily used to obtain such evidence by examining living and deceased members of the few remaining "barefoot" populations that have never worn shoes or elevated shoe heels.

Steven Hawking's Brilliant Brain and Asymmetrical Body Due to ALS

In contrast, Steven Hawking was bilaterally asymmetrical in posture and stature. His exceptional brain was likely to be similarly asymmetrical, due to his ALS (amyotrophic lateral sclerosis or Lou Gehrig's disease), which forced his entire body into a deformed structure that reflects – to an even more extreme degree - that of scoliosis, as apparent in **FIGURES 29A**.

His overall structural bilateral asymmetry was already evident in the picture from his college days, shown in **FIGURE 29B**. The asymmetrical size and shape of his eyes in a recent photograph strongly suggest similar underlying brain asymmetry **FIGURE 29C.**

Did Elevated Shoe Heels Ignite the Renaissance and Reformation, and the Rise of Modern Science and Technology?

The substantial physical asymmetries of Einstein and Hawkings suggest a possible correlation between modern brain asymmetry and exceptional intellectual ability, at least in some individuals. Remarkably, the historical period during which elevated shoe heels were introduced into use in Western Europe is the same period in which arose the beginning of modern science and technology that created the modern world. That might not be a coincidence.

Elevated shoe heels may have - in a totally inadvertent way - provided a brain boost to at least some individual modern humans that ignited the revolutionary explosion of technological invention and progress that occurred then. Although that direct causation seems almost unimaginable, the logical possibility clearly exists, given the correlation.

Sir Isaac Newton, for example, is shown wearing elevated shoe heels, but that might be an anachronism. Nevertheless, elevated shoe heels even may have given birth to the modern geek.

The Major Downside of Unnatural Modern Brain Asymmetry: Dementia

In April 24, 2016, David **Camarillo**, Ph.D. of Stanford University gave an excellent TED Talk entitled ***Why Helmets don't prevent concussions – and what might* (see www.ted.com**). Dr. Camarillo provides good evidence of the many fallacies in our conventional understanding of brain concussion and related dementia. In a concussed brain, the **jello-like brain tissue** in a critical central portion (shown in red) is being stretched by up to 50% of its normal volume. See **FIGURE 30**, which shows a brain concussion computer simulation.

The position of this maximally stretched portion is particularly unfortunate, because this stretched tissue resides in that portion of the brain that is the precise location of the principal network connection (again, in **red**) between the right and left hemispheres of the brain.

The physical brain structure forming the main network connection of the brain is known as the **corpus callosum**, circled in **red** as shown in the normal modern brain in **FIGURE 31.**

Separating the two hemispheres above the corpus callosum is a fissure, which contains the **falx** (not shown), a fibruous sheet of tissue running from the front to the back of the brain. The stiffness of the falx transmits unnatural torsional motion of the head containing the jello-like brain directly to the corpus callosum.

FIGURE 32 shows an abnormal modern brain subject to repeated concussions. The brain is shown below in, which is that of a retired former NFL football player who suffered from **chronic traumatic encephalopathy** (**CTE**). In this CTE brain, the corpus callosum is severely deteriorated: indeed, it shows more deteriorated than any other portion of the brain. In advanced CTE, the corpus callosum is disconnected and asymmetry between the hemispheres is extreme.

Repeated Asymmetrical Sideways Head Motion Causes Repetitive Stress Injuries to the Modern Human Brain, Possibly Causing Dementia

If extreme traumatic forces cause violent sideways motion that lead to acute injury such as **concussions and chronic traumatic encephalopathy (CTE)**, then highly repetitive abnormal sideways motion caused by shoe heels in running could cause repetitive stress injuries to the brain, albeit very gradually over time. In a lifetime, the unnatural cumulative effects would become apparent.

Moreover, the unnatural effects would be focused on the critically important corpus callosum, the principal physical connection between the left and right hemispheres. The shoe heel-induced brain torque discussed earlier (see again **FIGURES 28A-D**) would cause the tissue of the corpus callosum between the shifting hemispheres to stretch unnaturally.

There is a strong possibility that the same injury mechanism apparent on an acute basis in concussions brought on by major shocks also adversely affects the brain on a chronic basis as a result of the **repetitive stress of micro shocks**. Therefore, dementia itself could generally result from the repetitive micro-stress injury to brain tissue caused by the artificial shoe heel-induced unnatural torques that cause asymmetry in the modern human body and brain.

The latest research on chronic traumatic encephalopathy (CTE) supports the theory that this **repetitive micro-stress** could cause CTE itself as well. According to Dr. Ann McKee, the director neuropathogy at Boston University's CTE center, CTE is not the result of big hits creating concussions, but rather the result of a multitude of lessor blows sustained over many years (especially a long professional career) that is the underlying problem and the most significant factor.

If this is correct, then CTE could be either caused or aggravated by the abnormally fragile modern body, made so structurally and functionally by the repetitive abnormal torsion effect of elevated shoe heels over a lifetime. The abnormally fragile modern body simply exacerbates the effects of all injuries, whether accidental injury like falls or intentional injuries in sports like football hits.

Similarly, an April 18, 2018 study by Raquel Gardner et al. in **Neurology** indicates that even a mild concussion increases the risk of Parkinson's disease by 56% and a moderate to severe concussion increases risk by 83%.

Stroke Occurs in Brains with Significant Asymmetry Between the Hemispheres That Demonstrate Rotary Torsion: Again, A Coincidence?

Stroke is characterized by a portion of the brain which has died due to an abnormally reduced blood flow to it. As is evident in **FIGURE 33**, which is a CT scan of a stroke patient, the stroke has occurred in a brain with marked asymmetry between the frontal lobes of the right and left cerebral hemispheres (shown in **green**), in which their twisted positions evidence significant clockwise rotary torsion. The frontal lobes control the most complex intellectual processes of the brain.

Moreover, the portion of the brain tissue that has died (shown in **orange/red** on the left of **FIGURE 33**) is in the frontal lobe of the right hemisphere that has been pushed forward and compressed, probably subject to higher than normal pressure from abnormal clockwise torsion on a repetitive basis. The width of the affected right hemisphere is less than that of the unaffected left hemisphere, again suggestive of regular exposure to higher than natural compressive forces.

It is highly possible, obviously, that increased relative pressure on any portion of the brain would likely have an adverse effect on the flow of blood sufficient to avoid brain stroke. The higher than natural compressive forces that are present in hemispherically asymmetrical brains would produce that increased relative pressure.

It is therefore reasonable to speculate that elevated shoe heels increase the occurrence and severity of brain strokes by increasing brain hemispheric asymmetry, as demonstrated previously.

It Is Possible That Schizophrenia May Involve a Compressed Prefrontal Cortex and Dysfunctional Corpus Callosum

A characteristic of schizophrenia are thinner prefrontal cortex layers, which would also result from the right hemisphere being pushed forward abnormally, as observed with stroke in **FIGURE 33** above, which would thereby compress generally the entire prefrontal cortex, restricting its natural growth.*

> ***Carey**, Benedict (2016). Scientists Home In on Cause of Schizophrenia. In ***The New York Times***, January 28, 2016, A1. Summarizing report by Aswin **Sekar** … Beth **Stevens** & Steven **McCarroll** (2016). Schizophrenia risk from complex variation of complement component 4. In ***Nature*** 530, 177-183.

In addition, as discussed above relative to CTE, twisted asymmetrical brain hemispheres stretch the corpus callosum abnormally, physically degrading its structure and function. Since the corpus callosum provides the essential communication between the two hemispheres, when it is seriously degraded the two hemispheres are forced to act almost independently. The two hemispheres thus run in parallel in unnatural virtual isolation, without normal coordination or feedback between them.

It is logical to assume that would result in confusion, such as hallucinations in the form of the typical schizophrenic symptom of voices in the head. Again, it is logical to hypothesize that they are the voices of one hemisphere commenting on the behavior of the other.

In effect, a victim of schizophrenia may be under the control of two nearly independent hemispheric brains that are constantly fighting for temporary control of the individual's consciousness. Each brain is unaware of the other, due to the lack of feedback normally provided by an intact corpus callosum.

To be clear, other factors besides elevated shoe heels are also likely to create the brain asymmetry that may be the underlying structural cause of schizophrenia. For example, the club foot is a well-known birth defect that is essentially a hyper-supinated foot and is therefore likely to cause brain asymmetry in more or less the same way attributed to the shoe heel-induced supinated foot.

In consequence, that particular birth defect and other asymmetry-inducing factors are likely to cause schizophrenia and the other mental problems described in this article, as well as most of the other effects throughout the modern human body attributed here to the elevated shoe heel.

A Dysfunctional Corpus Callosum Also Could Possibly Worsen Common Mental Disorders such as Addiction, Anxiety, Depression, and Obsession

Recent research indicates that mental disorders such as addiction, anxiety, depression, and obsession

> … involve uncontrollable and endlessly repeating loops of rumination that gradually shade out reality and fray our connections to other people and the natural world. The ego becomes hyperactive, even tyrannical, enforcing rigid habits of thought and behavior.*

*__Pollan__, Michael (2018). ***How to Change Your Mind: What the New Science of Psychedelics Teaches Us About Consciousness, Dying, Addiction, Depression, and Transcendence***. Penguin Press. From an adapted essay, "The New Science of Psychedelics "in ***The Wall Street Journal***, May 5-6, 2018, C1-2.

Since the corpus callosum is made artificially deformed and dysfunctional by shoe heels, natural communication between brain hemispheres is blocked, thereby potentially trapping the ego within a single hemisphere. That would force normal outbound communication to the other hemisphere to rebound instead, staying within that single hemisphere, thereby forming the pathologically uncontrollable "endlessly repeating loops" that are characteristic of the above mental illnesses.

In addition, the prefrontal cortex is one of the main areas of the brain affected by depression. The prefrontal cortex is the portion of the right hemisphere that is most compressed in the modern brain as a result of its structural deformation by the unnatural rotary torsion caused by elevated shoe heels, as shown in **FIGURE 33** above relative to strokes.

Alzheimer's Disease May Possibly Be Caused by Abnormal Brain Tissue Stretching

Even the plaque in the brain tissue of **Alzheimer's** patients may result from the unnatural stretching caused by shoe heel-induced asymmetry. Previous studies have shown that mechanical forces create unnatural tensile strain that disrupts the ability of cells to develop and continue functioning normally. That disruption has been implicated in many diseases such as osteoporosis, deafness, atherosclerosis, cancer, osteoarthritis, muscular dystrophies, and developmental disorders.*

*__Sears__, Candice et al. (2016). The many ways adherent cells respond to applied stretch. In the ***Journal of Biomechanics*** 49: 1347-1354.

The brain's jello-like consistency makes it especially vulnerable to the unnatural stretching that I have described. The disruption effect is potentially worse than in other parts of the body. The brain's 85 billion neurons are structurally supported by glial cells and its neurons are connected to other neurons with about 100 trillion branches that terminate in about 100 trillion synapses. Unnatural cellular repetitive stretching poses a genuine risk to these fragile structures.

A review of the available evidence, moreover, indicates a close relationship between cognitive disorders and gait disorders.** The gait disorders created by shoe heels may predate the cognitive disorders and they may, in fact, cause them or accelerate their natural progression.

> ****Valkanova**, Vyara and Ebmeier, Klaus P. (2017). What can gait tell us about dementia? Review of epidemiological and neuropsychological evidence. In ***Gait & Posture*** 53: 215-223.

Other Mental Diseases

Ironically, many or even most forms of mental illness may also be either caused and/or aggravated by elevated shoe heels in the manner describe above. A recent study has tied concussions in teenagers to a greater risk for them developing **multiple sclerosis**.*

> ***Montgomery**, S. et al. (2017). Concussion in adolescence and risk of multiple sclerosis. In ***Annals of Neurology***, Oct.: 82(4):554-561.

In addition, I was told recently by a medical doctor** that virtually **all of his mental patients at St. Elizabeth's Hospital, with a wide variety of typical mental diseases, had splayed feet that were twisted to the outside**, as happens typically as an excessive pronation compensation to the lower limb misalignment shown previously in **Figure 10**. Notably, his patients were unique in that they were in a research ward and were therefore not undergoing drug or other treatments that might alter their diseased condition into some untypical mental or physical state. Psychiatric literature, moreover, often portrays mental patients with an abnormal, even significantly impaired gait.

> **Although this data is only composed of anecdotal testimony by the medical doctor, he is an unusually well qualified individual observer. In addition to his medical degree, he holds a Ph.D. in Electrical Engineering and a law degree as well.

The former St. Elizabeth's doctor has always assumed that his patient's mental conditions caused their splayed feet. This assumption, of course, is based on simple correlation rather than causation. In fact, no known mental factors cause splayed feet.

The doctor assumed that mental abnormalities may cause the physical abnormalities associated with them. This top-down assumption is plausible, particularly without an alternative explanation. However, in my view, a bottom-up assumption based on what has been previously presented in this paper is far more credible, given the specific causative bio-mechanisms that have been clearly identified and are well-proven in settled peer-reviewed research.

Taking a bottom-up approach from the feet and shoe heels is also supported by the fact that the most critical and basic function of all for the animal brain is to control its body's motion. The brain evolved specifically to make animal motion possible and coordinating body movement remains its primary function in humans.

If shoe heels deform the basic structure and core function of the modern human body, degrading its capability to move naturally, it follows directly that the structure and function of the modern human brain may also develop abnormally in form and function. In my view, it follows that sometimes that brain structural abnormality is severe enough to result in mental disease in its many varieties and degrees.

The earliest description of **Parkinson's disease** by James Parkinson himself (1755-1824) supports this fact-based explanation. Parkinson, in fact, overtly suggests its link to the act of running (bolding added):

> SHAKING PALSY. (Paralysis Agitans.) Involuntary tremulous motion, with lessened muscular power, in parts [limbs] not in action and even when supported; **with a propensity to bend the trunk forward, and to pass from a walking to a running pace**: the senses and intellects being uninjured.*

*From ***The Enlightened Mr. Parkinson*** by Cherry **Lewis** (2017). Pegasus.

The Yips or Loss of Fine Motor Skills in Athletes

The far-reaching effects of shoe heels could possibly even extend to more minor mental afflictions, such as the dreaded **yips**, which is the loss of fine motor skills in athletes. The yips are, for example, the scourge of senior golfers trying to sink a close-in putt, because the yips manifest themselves as twitches, staggers, jitters, or jerks.

The yips are probably due to a breakdown in communication between the two brain hemispheres. Slowly increasing damage to the corpus callosum occurs with age. The damage is caused gradually by excessive tissue stretching in the corpus callosum. The tissue stretching occurs from the abnormal twisting motion that creates the asymmetrically shifted hemispheres of the unnatural modern human brain.

Essentially, the right and left hemispheres can no longer communicate well enough with each other to smoothly coordinate their separate and independent control of the right and left arms into unitary control of a precise golf swing, for example.

Of course, the problem is a more general one, since virtually any motion of the bilateral human body during standing or locomotion requires fairly precise coordination between both hemispheres of the brain to integrate control of both sides of the body into one motion. The yips may just show up first and therefore may be an initial indicator of greater, more general coordination difficulties in the future for an individual experiencing them.

22. For more on citizen science, see www.CrowdAndCloud.org, and Caren **Cooper** (2016), ***Citizen Science: How Ordinary People are Changing the Face of Discovery***. The Overlook Press: New York, N.Y.

23. For more specific help in running, see Tom Perrotta (2018). "How Can You Make Running Less Painful" in **The Wall Street Journal**, April 10, 2018.

https://www.wsj.com/article_email/how-can-you-make-running-less-painful-1523280896-lMyQjAxMTE4OTEzMTAxOTE5Wj/

24. A recent example is the titanic $1 billion fiasco in brain research, as summarized in a ***Scientific American*** article by Stefan **Theil** titled, "Trouble in Mind" October 2015, pages 34-42. See also Henry **Markram**, "The Human Brain Project" in ***Scientific American***, June, 2012, pages 50-55

25. Lieberman, Daniel L. (2013). ***The Story of the Human Body***, Pantheon Books: New York, page 244 and footnote 72 on page 412. See also **Table 3** on page 173, which is a (partial) list of fifty **Hypothesized Noninfectious Mismatch Diseases**, from Alzheimer's disease to stomach ulcers.

26. Robbins, Steven E. & Hanna, Adel M. (1987). Running-Related Injury Prevention Through Barefoot Adaptations. In ***Medicine and Science in Sports and Exercise*** 19, **148-156**.

Final Note: FIGURE 1B from the 1939 James study is not completely accurate, in that James arbitrarily aligned together the heels of the two footprints that are superimposed for comparison. He put the two heel prints exactly on top of each other so that they appear to be as one. In reality, the heel of the **supinated** foot also is displaced by rolling to the outside in the same way as is the forefoot, although the amount of its outward displacement is less than that of the forefoot, so that James' figure is still a fairly accurate comparison.

It is notable that this outward rolling motion of the calcaneus under body weight load is what causes the characteristic heavy wear on the bottom of the heel on its rearmost lateral portion. The calcaneus becomes tilted on its rearmost lateral portion, which also results in the abnormally enlarged development of the lateral calcaneus tuberosity, which is essentially absent in never-shod barefoot populations.

This highlights the fact that during load-bearing the location of the subtalar joint and therefore its axis is always changing in three-dimensional space, not fixed as in the classic Root et al. studies. In the shoe heel-induced supination position of the foot, the subtalar axis is raised in the sagittal plane and rotated externally to the outside in the horizontal plane. Conversely, when the foot pronates during body weight load-bearing, the subtalar joint axis is lowered in the sagittal plane and rotated internally in the horizontal plane.

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