FIRST DRAFT*

MODERN HUMAN ANATOMY:

The Incredible Effect of Shoe Heels on the Human Body

Brief Introduction

By way of introduction, I am a runner. Or more accurately, and most sadly, little more than a former runner, like the vast majority of longtime runners. Relatively early on in my running career, which really began in a serious way as a young adult, I began to have an assortment of overuse injuries. That set me on a search for cures.

Initially I was just looking for solutions for my own persistent problems. Eventually, out of the frustration of not finding any existing running shoes or orthotics that helped me, I ended up pioneering the first research and development on barefoot-based designs for shoe soles.

I had discovered back in 1988 that the human barefoot has much better lateral or side-to-side stability than conventional shoe soles. My goal then was therefore to invent a new shoe sole structural design that retained that much better stability of the barefoot. The barefoot designs I developed at that time preserve the wider, rounded shape and flexibility of the natural human foot sole in order to prevent ankle sprains, the most common sports injury (as well as the most common cause of Emergency Room visits).

Within 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 fifty footwear and footwear-related U. S. patents are listed on my website: www.AnatomicResearch.com.)

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

After three more years, in 1994, I was able to license that patented technology to Adidas, which called it ***barefootwear*** during initial development and almost immediately made it their core technology in all categories of new footwear (not for classics, which are old models with continuing popularity, like the Stan Smith tennis shoe). Adidas began marketing the shoe sole technology in 1996 as "***Feet You Wear***" using their star athlete endorsers like 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, many models in every category. However, the patent license was terminated then, at the end of several years of litigation over its terms.

Since then I have become ever more focused on an investigation into an entirely different aspect of footwear design. It is a feature that is also a major structural departure from the natural design of the human barefoot.

Investigating a Puzzling Effect of Elevated Shoe Heels

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.

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

Over many years, however, the original investigation slowly evolved into trying to solve an increasingly complicated anatomical mystery. It has been full of hidden twists and turns and dead-ends, as well as some very old clues that seem obvious now, but only in hindsight.

The unexpected solution to the anatomical mystery is one that has been completely overlooked. The solution is that, despite their almost matchless apparent triviality, elevated shoe heels have deformed the modern human body, from head to toe. As difficult as that undoubtedly is to believe – if not totally preposterous on its face – 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. How anything as commonplace and thoroughly innocuous as shoe heels manage to do so is revealed in the article that follows. It is a brief overview of far more extensive research detailed in my new book of the same title (which is cited at the end of the article, with a website link).

That research firmly supports the conclusion that elevated shoe heels have, in fact, caused the reshaping of modern human bone structure, and thereby the basic ability of the modern human body to function naturally. It is all based on a solid foundation of settled science, including many hundreds of peer-reviewed articles from the best medical and scientific journals, all cited in the extensive endnotes (which also include the most relevant pages and figures of referenced articles) and an equally extensive bibliography.

The First Clues

Good mysteries often have a clue planted near the beginning, one that is often too trivial and unpromising not to be overlooked until much later, when its central importance in solving the mystery is a sudden, complete surprise. This particular case begins with a set of two such apparently innocuous clues that have been overlooked for a very, very long time.

Many classic mysteries involve fresh footprints at the crime scene, but it is just plain coincidence that in this case, too, the first clues are footprints. However, these are not fresh footprints. They have been buried - since 1939 - in a long forgotten medical journal report.

The trail of first clues starts in an unexpected place. The report is from a Clifford **James** at the Melanesian Mission Hospital in the island of Malaita, next to Guadalcanal in the British Solomon Islands in the South Pacific. Although this could hardly be a less current or more obscure source, at least the medical journal is the prestigious British journal, the ***Lancet***.

Despite their age and obscurity, the footprints turn out to provide both unique evidence and a valuable direction in which to go in searching for a solution to the mystery. The mystery itself, unlike most popular mysteries, is not about solving a murder. Nor is it fiction.

It does, however, involve life and death, because it is a medical mystery, one that involves many real lives and many real deaths. So many, in fact, it is far more likely than not that it also involves you, and your own life and death. How that can possibly be will become all too apparent as the mystery is unraveled bit by bit for your own eyes to judge.

Starting with just the few footprint clues, solving the mystery step-by-step, we will uncover a shocking medical discovery of many major human anatomical deformities that somehow have remained completely hidden 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 unlocking the mystery.

THE FIRST CLUE: Different Races Have Virtually Identical Footprints

In the **first set of footprints**, **FIGURE 1A**, two separate bare footprints are superimposed on each other, the first of a barefoot Solomon Islands native (dashed line) and the second of a European (solid line). Both had never worn shoes (which of course makes the European a very rare laboratory specimen). The footprints are essentially identical.

FIGURE 1A provides unique evidence that race is definitely not a factor in determining the natural, inherent shape of the human foot. Both racially different feet were the same, and both never wore shoes.

Those identical footprints indicate that all human feet have the same basic shape if left to develop bare, without the influence of footwear. Foot shape is fundamentally the same for both Caucasians and Polynesians.

THE SECOND CLUE: Normal Shoe Use Creates a Different Footprint

In the **second set**, **FIGURE 1B**, another two bare footprints are superimposed on each other. Again, the first of a barefoot island native (dashed line) and the second of 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 what proves to be the most crucial clue. It shows starkly what will turn out to be the most important change to feet made by shoes.

That change is that the shoe-wearing European has a bare footprint (yellow solid-line) that is rolled unnaturally to the outside relative to the natural barefoot footprint. Technically, this rolled outward foot position is called **supination** (in contrast to rolling inward, which is called pronation).

FIGURE 1B provides strong evidence that shoes must be the cause of this difference in foot shape between races, since shoe usage is the only difference between the two footprints.[1]

The old footprints in the **James** study provided the first really definitive evidence ever found that shoes alone change the shape of the modern human foot, whereas racial differences do not.[2] (Although some earlier research does take significant first steps in that direction.)

It is important to note that this overlooked simple but direct evidence from James contradicts the widespread general belief that human anatomical differences between races are race-based, unalterably determined by genes.

However, an even more important question remains: how exactly do shoes change the feet? Many studies before and since have implicated shoes as the prime suspect underlying the many well-known problems of the modern foot, including 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 provide us with a key line of questioning to begin our investigation in earnest.

Some Background on Shoes and Running

First of all, we will focus specifically on the following question: why and how exactly do shoes cause the foot to roll to the outside, to supinate. That is the central question.

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 prestigious scientific journal ***Nature*** that evolution had created a human body that was fundamentally designed to run[3].

They presented compelling evidence that humans were the best endurance runners in the animal kingdom. Humans excel at "persistence hunting" in which they successfully run down far faster antelopes and other game in long hunts over relatively great distances. Such persistent hunters succeeded by being efficient runners that did not overheat like their prey did. And those hunters clearly did not evolve to do this over hundreds of thousands of years while wearing modern running shoes.

In 2009, Christopher McDougall's best-selling book, ***Born to Run***, was published[4]. Echoing pioneering scientific work by Harvard professor Daniel Lieberman and others, McDougall recounted strong evidence that the human body has evolved to run as its primary structural function and to do so relatively injury-free while barefoot.

In stark contrast, injury rates in modern running shoes have remained unchanged since the 1970's to as high as 70% per year, when running and jogging became widely popular.

Around those scientific facts McDougall wove the true story of an incredibly tough 50-mile race in the rocky, hilly Copper Canyon of Mexico. The race was won by an untrained primitive runner, a Tarahumara Indian, who wore only semi-barefoot sandals. He triumphed over the all-time-world's-best ultramarathoner, Scott Jurek, a modern Western champion who wore modern running shoes.

After the book was published, an almost overnight barefoot running revolution was born. Many runners began going barefoot or running in more barefoot-like "minimalist" shoes like the Vibram Five Fingers. Many of the leading biomechanics scientists involved in running shoe research and design announced publicly that it was time to "start over."

The impact of the barefoot running revolution, which was sort of a popular uprising against conventional footwear, stirred a reaction in the footwear science community that had been already been growing for about a decade. Even as early as 2005, one of its leaders and pioneers, Martyn Shorten, suggested 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]. 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]

But now, several years later, we have arrived at a major impasse. The barefoot running revolution rather quickly fizzled out. The reason is pretty simple: high injury rates overall have not changed much, if at all, either with "minimalist" running shoes or by going barefoot. In reaction, "maximalist" running shoes have also come, but brought no significant improvement. And conventional running shoes have remained essentially unchanged.

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

Unfortunately, no. Dr. Craig Richards authored in 2008 what I think is the most important formal research paper ever published on the design of modern running shoes[8]. Simply put, his paper makes unequivocally clear that there is no existing scientific evidence - none whatsoever - supporting any of the supposed benefits for using modern running shoes and their many different technologies.

He even challenged major footwear companies to provide supporting evidence. They have not, apparently because there is none. Nor has any such evidence been published independently.

As far as I know, all of the actual research done in-house at footwear companies is completely secret, so there is no public information available on the scientific basis for any of their footwear products. All we have to go on is their advertisements.

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

Unlike walking studies, 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.

Instead, they 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. So, at present we know absolutely nothing about the running biomechanics of most of the modern human population.

Finally, only a few studies of very limited scope have used barefoot runners as test subjects who have never worn shoes. More on these fundamental problems with existing running research later, at the end of Endnote[11].

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

We are now hopelessly trapped in a dead-end. There are no obvious new alternatives left to try, only old ones to try again. If we were born to run, why does running unavoidably cause so many injuries?

As we shall see, it turns out that we just never understood the real problem, which involves a new and different understanding of modern human anatomy and basic biomechanics.

As you read on, always keep in mind during this journey the simple evidence you have seen in **FIGURE 1B** above, that **shoes cause feet to roll unnaturally to the outside;** that is, to **supinate** abnormally. That clue is the primary key to unlocking the deepest part of the mystery that is uncovered here.

The Automatic Reaction of the Ankle Joint to Elevated Shoe Heels

The lower leg bone is the shinbone (the tibia). The shinbone is joined to the ankle bone (the talus) of the foot to form the ankle joint. The ankle joint is a fairly simple joint that works like a hinge. It has an easy to understand structure and function.

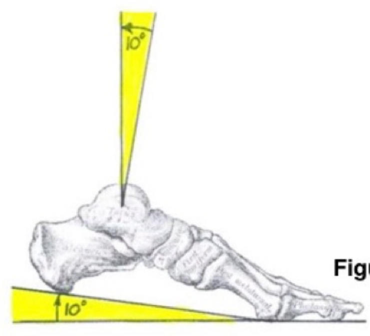
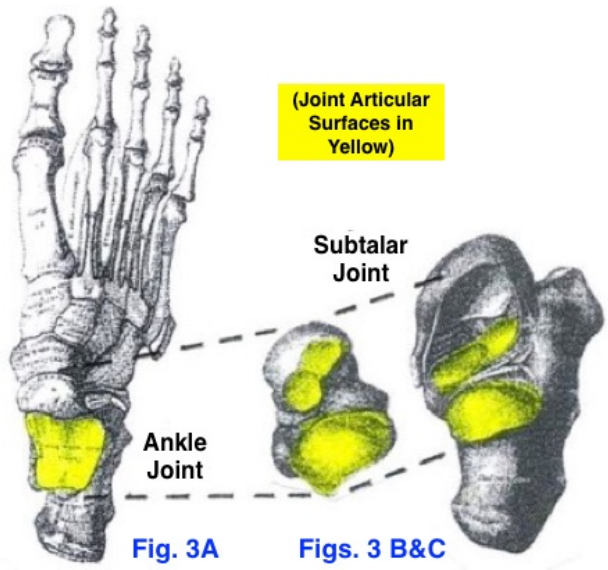


Figure 2B

So too, putting an elevated shoe heel 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, the leg is unconsciously and automatically straightened from the slightly bent knee position the higher heel causes. The shinbone automatically moves backwards in an amount equal to the amount by which the elevated shoe heel tilts the foot downward. Otherwise, you fall forward on your face. See **FIGURE 2A.**

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 adjustment maintains the same upright, straight leg standing position. It is a simple and automatic compensation. The ankle joint is then in what is called a plantarflexed position. See **FIGURE 2B.** There is nothing complicated in this automatic, self-adjusting reaction to the elevated shoe heel that takes place in the ankle joint. However, hidden underneath is a much more complicated joint reaction.

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



The foot's main ankle joint is shown in **FIGURE 3 A**, with part of the upper surface of the ankle bone (talus) forming the ankle joint's articulating surface 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 ankle bone (talus), which forms the upper articulating surface of the joint (**FIGURE 3B**), and the heel bone (calcaneus), which forms the lower articulating surface (**FIGURE 3C**). As you can see by comparison, the subtalar joint has a much more complicated structure and apparently different function than the ankle joint.

The subtalar joint also is affected directly by the elevated shoe heel. However, it is dissimilar and therefore affected in a much different way than the ankle joint because of its more complicated structure and function.

It doesn't need to operate like the ankle joint because the ankle joint already provides the simple hinge joint that is necessary to allow the shinbone to move forwards and backwards over the foot.

The principle function of the subtalar joint is different. It provides sideways, left to right motion of the foot on the ground. This side-to-side motion capability is essential so that the foot can adapt to irregularities in the ground surface during locomotion. Conceptually, that's pretty straightforward too.

But the subtalar joint also has a less obvious function. It is an even more essential component of a locomotion system that controls the rigidity of the foot. This rigidity control is critical so the foot can fulfill two most basic but entirely different functions while walking or running.

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

During the first half of the stance phase after landing, the foot must be flexible so as to absorb the shock of a ground reaction force produced by our full body weight when we land and to adapt to the shape of the ground. During the second half of the stance phase, the foot must be rigid to function as a propulsive lever to push off the ground.

The subtalar joint performs this dual and contradictory role by enabling what is mostly a slight sideways rolling motion of the foot on the ground. The foot's sideways rolling motion is called pronation when rolling to the inside to absorb landing shock through greater flexibility.

During pronation, the main longitudinal arch of the foot depresses toward the ground, and the heel bone tilts inward from a neutral, generally vertical position. At this point of the running stride, the heel bone – the base of the subtalar joint -- is load-bearing on the ground.

The foot's slight sideways rolling motion is called supination when rolling to the outside to create a more rigid propulsive lever in a plantarflexed position. During supination, the main arch is raised and 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 not load-bearing

This rigid propulsive lever is unique to the human foot. Our closest living non-human relatives, the chimpanzees, 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 is well understood. What has somehow been overlooked almost entirely is that **the elevated shoe heel also 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 is artificially tilted out and the foot becomes more rigid. And this happens when the heel bone is load-bearing on the ground. In a literal sense, this is a pivotal change. When standing upright, the foot is no longer in a natural, neutral position.

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

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

Elevated Shoe Heels Automatically Shift the Position of the Subtalar Joint Outward

First, 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 level on the ground, the plantar aponeurosis is relatively loose, so the foot is flexible and most capable of conforming to any irregularities of the ground, in order to provide a stable base of support for the leg. See **FIGURE 4A**, which shows the position of the flexible supporting foot.

When the heel bone is raised during the propulsive phase of running or walking, it automatically bends your toes upward toward you. That 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 out the heel bone. This mechanism turns the foot into a rigid propulsive lever with which to push off when running, jumping, or walking. See **FIGURE 4B**, which shows the position of the rigid propulsive foot.

The elevated shoe heel artificially puts the foot into this position all the time – including throughout the entire load-bearing phase -- not just during the toe-off propulsive phase of running or walking.

The Natural Windlass System (Without Shoe Heels)

Second, 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 foot is automatically plantarflexed by the elevated shoe heel, the foot is supinated by the windlass action, which raises the longitudinal arch, and the midtarsal joint is gradually locked 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, which shows a front view of the ankle bone (talus, in yellow) and underneath it, the heel bone (calcaneus), both of which are joined together by the subtalar joint. **FIGURE 5A** shows how the subtalar joint operates. The ankle bone rotates on top of the heel bone – tilted inward in pronation and tilted outward in SUPINATION, shown on the right.

In the SUPINATED position on the right, the axis of each of the joints connecting the front of the ankle and heel bones to the rest of the foot are crossed, locking the joints to make the foot rigid for propulsion. In pronation, they are parallel, unlocking the subtalar joint. The windlass mechanism is the principal way the position of the subtalar joint is synchronized with the position of the ankle joint.

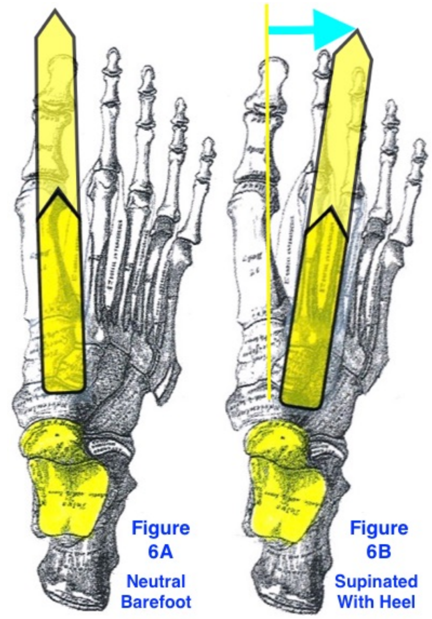
Both the windlass action of the plantar aponeurosis and the locking role of the midtarsal joint have been very well known in the associated fields of anatomy and biomechanics for many decades, as is their mutual interaction with the subtalar joint to form an effective part of the human locomotion system.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

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

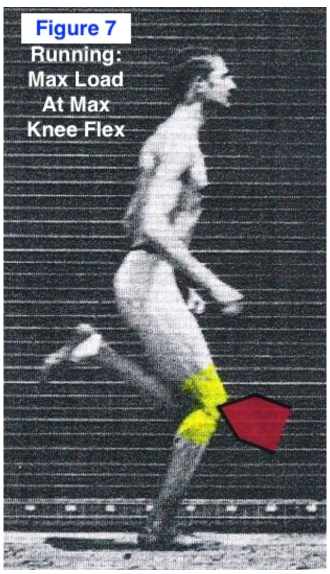
What is also definitively settled science is a different bio-mechanism. Any foot supination motion, such as that caused by the elevated shoe heel, automatically rotates the lower leg (or tibia) to the outside, as demonstrated in a classic study by Gustav **Rubin**[9], shown below in **FIGURE 5B**. That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

FIGURE 6A shows natural, unshod right foot and therefore un-twisted midstance right knee position pointed straight ahead. The ankle joint is pointed straight ahead, when you flexed your knee to absorb the force of your full body weight when walking or running.

In contrast, **FIGURE 6B**, which shows the unnatural, maximally loaded, tilted out right knee position caused by shoe heel running at the maximally loaded midstance position of **FIGURE 7**. The outwardly rotated ankle joint forces the knee to the outside. **FIGURE 6B** also shows that the inside (medial) half of the knee joint abnormally carries most of that maximal load, as much as 80-90% for some individuals.



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



Running plays a decisive role in producing abnormal structural change. That is because, forced by the abnormal twisted outward foot supporting it, the knee is also twisted outward while flexed about **40°** at the maximal load-bearing point during the midstance phase of running (shown in **FIGURE 7**). The greatest repetitive stress on bones and joints occurs then, at about 2-3 times body weight.

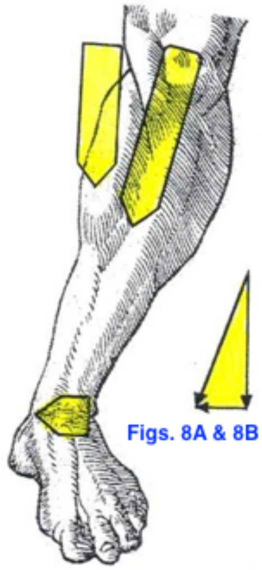
This is critical in altering the natural development of bone structure, since according to Wolff's Law, bone formation occurs in reaction to the maximum stresses to which the bone is routinely subjected. For the human body, the peak routine body weight load occurs when running, especially during childhood, when running is a constant activity. (One of the most frequent parental commands is either "Don't Run!" or "Stop Running!"- both of which are routinely ignored.)

The typical midstance running position shown below in **FIGURE 7**, with a peak load of **2-3 times the runner's full body weight** at the same time that the right knee is maximally flexed about **40°** in running. This is a critically important difference from walking, in which the load-bearing leg is generally **straight** when it passes directly underneath the walker and bears only about **½ of the walker's body weight**. This is a critically important difference.

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

Incidentally, the footprints clues cited in the James report (**FIGURES 1 A&B**) are all the more powerful as evidence because the footprints were taken with knee bent forward, forced down, supported on that single leg alone. So, it was taken in roughly the typical midstance running position shown in **FIGURE 7** above (although at only about 1 full body weight, rather than the 2-3 times full body weight typical in running).

Runners' Legs Forced into an Inherently Unstable, Tilted-Out Position



Figs. 8A & 8B

FIGURE 8A below shows a front prospective view of the tilted-out runner's leg of **FIGURES 6B** above, with the resulting 2-3 times body weight of the runner being angled from vertical, following the support structure provided by the lower leg bone. Whereas the leg would be stable if vertical, it is unavoidably unstable in the tilted-out position.

In the terms of simple classical physics, this angled vector of body weight resolves into a vertical component vector and a horizontal component vector, as shown below in **FIGURE 8B**. The horizontal component is the key factor, since it unnaturally forces the subtalar joint inward, causing the foot to pronate inward more than naturally needed.

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

Summing up, as shown above in **FIGURES 6B & 8A, the shoe heel forces the knee to tilt unnaturally <u>outward</u> in the frontal plane (toward a bow-legged position) and rotate externally in the horizontal plane.**

Simultaneously the ankle is unnaturally forced <u>inward</u> by the unstable force vectors resulting from the tilted lower leg, as shown in FIGURE 8B, resulting in unnatural pronation. This <u>dual</u> interaction is strictly mechanical and occurs simultaneously. It is automatic and unavoidable.

Shoe Heels Artificially <u>Decouple</u> Natural Joint Motions of the Lower Limb

Although the static lower leg bio-mechanisms described above in **FIGURES 4A&B, 5A&B, 6A&B & 8A** are old and settled science, many studies in recent decades indicate clearly that these static mechanisms are "**decoupled**" when running[10].

However, to clarify, the term "decoupled" used in the biomechanical studies is misleading, because its English definition includes two conditions, <u>either</u> "to reduce <u>or</u> 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 absolutely not an either/or coupling. Instead, as used in the above referenced studies, "decoupled" only means reduced but still directly connected. In point of fact, <u>none</u> of the studies - static, walking, or running – challenge the well-established biomechanical fact that foot supination/pronation is directly coupled to lower leg external/internal rotation.

Rather, the only question raised by the studies is whether the <u>ratio</u> of foot motion to leg motion stays the same or is reduced during different forms of locomotion, especially during running, and, if reduced, by how much.

More specifically, the decoupling studies have found that joint linkages when measured stationary are observed to be relatively rigid relationships, but apparently become more flexible under dynamic conditions, since the ratio relationship between them is reduced then. That observation could be interpreted as generally meaning that this known static bio-mechanism has less effect in a dynamic situation, perhaps much less.

If so, 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. So that is potentially a significant issue, given the central importance of running to the analysis outlined above relating to **FIGURES 6B & 8A**.

It is also an important riddle in a scientific sense, since no one knows why decoupling happens.

Until now.

During running, the elevated shoe heel itself -- as the automatic bio-mechanism described above in **FIGURES 6B & 8A** - actually causes the observed **decoupling** of the foot and lower leg bio-mechanism. It is not hard to understand why this must be so, based on a number of excellent peer reviewed biomechanical studies.

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

During running with elevated shoe heels, the 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.

The **first torsion** is produced naturally by the static lower leg bio-mechanisms described above in **FIGURES 4A&B, 5A&B, 6A&B & 8A.** Those bio-mechanisms 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 above by Rubin in **FIGURE 5B**.

The **second torsion** is produced artificially by the elevated shoe heel itself -- as the automatic bio-mechanism described above in **FIGURES 6B & 8A.** That second mechanism is also logically based on exactly the same bio-mechanisms that would otherwise be expected from stationary testing, also as shown above by Rubin.

The two torsions offset each other to produce a net torsion that determines the observed joint coupling during running. Unfortunately, all of the running decoupling studies listed above in Endnote[10] have failed to account for the presence of the shoe heel-induced torsion, which is strictly based on settled science as described above and therefore must be included in order to be scientifically valid.

By ignoring the presence of the torsion effect of elevated shoe heels, all of those studies have simply interpreted the observed coupling during running to be decoupled from their established static natural values for some unknown, mysterious reason. That is a critical error of omission by failing instead to correctly interpret the coupling as a net value of two torsions, one natural and one artificial.

Simply put, shoes heels directly cause the decoupling, thereby substantially disrupting the otherwise direct joint linkages. To put it another way, **decoupling is simply the direct effect of shoe heels**.

Firm Research Support for Shoe Heels as the Source of Joint Decoupling

Solid support for this conclusion in a biomechanical research study can be found in data from the earlier cited recent study by Steffen **Willwacher** et al. The study is the winner of the **Nike Award for Athletic Footwear Research**, the highest award presented at the **XII^th^ Footwear Biomechanics Symposium** in Liverpool, UK 2015, a biannual conference sponsored by the **International Society of Biomechanics.**

Using some formal analysis, the actual physical existence of the artificial decoupling shoe heel bio-mechanism can be proven mathematically using the unusually large data set from the Willwacher study**.** The proof is surprisingly straightforward. It is somewhat technical, but you can follow the summary of the full analysis in Endnote[11]**.**

Summarizing the precise mathematical results in words, the Willwacher data indicates that measured midstance pronation of the foot produces much less internal tibia rotation than forecast by Rubin's static coupling ratio. But the missing internal tibia rotation matches the amount of external tibia rotation due to the shoe heel-induced unnatural supination of the foot, again using Rubin's ratio.

Essentially, the runner's foot is pronating in an unnaturally excessive additional amount to compensate for the artificial supination effect of the elevated shoe heel, which unnaturally rotates the tibia externally – the mechanically unstable position shown in **FIGURES 8A&B**. Whether a runner's knee ends up in a bow-legged, knock-kneed, or neutral position is a specific compensation determined by each individual's anatomy to find biomechanical equilibrium in reaction to the artificial destabilizing effect of shoe heels.

The artificial elevated shoe heel has in effect locked the foot into an abnormal supination position (with externally rotated tibia) through most of its full range of pronation and supination motion during the stance phase in running.

So, summing up, a puzzling decoupling mystery can apparently be solved by just following the lead provided by our original footprint clues. You might rightly ask if there is some other, competing scientific explanation for the decoupling effect based on empirical data pointing in a different direction. The answer is no. The existing consensus explanation is that it just happens, which is more or less to say that it happens auto-magically.

The unavoidable conclusion calls to mind the famous quote by Sherlock Holmes, "when you have eliminated the impossible, whatever remains, however improbable, must be the truth." The bio-mechanism created by the elevated shoe heel on the subtalar joint described above associated with **FIGURES 1-8** is the simple physical reality, however improbable - all scientifically factual, based on solid peer-reviewed research. The possibility that it is not basically correct has been eliminated.

So, given the reality of the shoe heel bio-mechanism, then it must have had structural and functional effects on the human body during running, and very likely major ones given the maximal forces involved, despite the improbable truth that otherwise thoroughly innocuous shoe heels actually have had such enormously consequential power over our bodies. Starting with the knee in **FIGURE 9**, we can follow the evidence of that truth throughout the modern human body.

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

But first some further proof of the shoe heel bio-mechanism itself. As seen in the Knee Moment Frontal Plane graph of Figure 4 of the same study by Steffen **Willwacher** and others[11] (again, awarded the greatest formal prize in footwear biomechanics), there is strong evidence of 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.

There is also a similarly powerful **external rotation torque** in the horizontal plane, 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 expected from the previous discussion of **FIGURES 4A&B, 5A&B, 6A&B & 8A**, both torques are at a peak at midstance when the knee is maximally flexed about **40°** and under peak body weight load.

What really stands out in the data, as summarized in **FIGURE 8C**, is that the peak of **external knee adduction moment (or torque)** in the frontal plane extends almost all the way from about **20°** to **60°** of the stance phase. In other words, the peak is not really a peak, but rather a massively extended plateau of powerful unnatural torque forcing the knee into an abnormal varus or bowlegged position.

So, the dual torques shown in **FIGURES 8C** above act powerfully 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**, as is predicted by the preceding discussion of the biomechanical effect of conventional shoe heels. (Note the exceptionally confusing way in which the two sets of figures use the opposite directional terminology, **add**uction or **abd**uction, to describe exactly the same knee joint torque).

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

Avoiding this confusing **abd**uction versus **add**uction terminology, an important recent study of runners indicates that, at the maximum **40°** flexed position of the runner's knee (in the sagittal plane), there is an average of about **8° of knee varus (bow-legged, tilted-out) position** (in the frontal plane).[12]

A different, earlier study 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.[12] These studies confirm the unnatural knee varus-inducing effect of elevated shoe heels noted above.

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 cited above).

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

So, we have seen from the foregoing that 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, it is the biggest single factor altering the known static joint mechanisms by decoupling them, and yet – extraordinarily - it has remained unknown and unaccounted in the existing research studies on running biomechanics cited above, and likewise omitted in all other research studies.

The result is that this unknowing but highly critical omission has functioned, in effect, as a **key** to encrypt all the empirical results of these running studies, making their results an undecipherable jumble of unrelated numbers with no observable underlying connection. The direct result has been that the decoupling effect discussed above has remained a mystery for decades.

Only by using the **key** – knowledge of the artificial factor of the biomechanical effect of 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 accurate science can be built.

But that is only the first step. But this confused current state of affairs is made far worse by an additional factor, also an unknown factor unaccounted for in all those existing research studies.

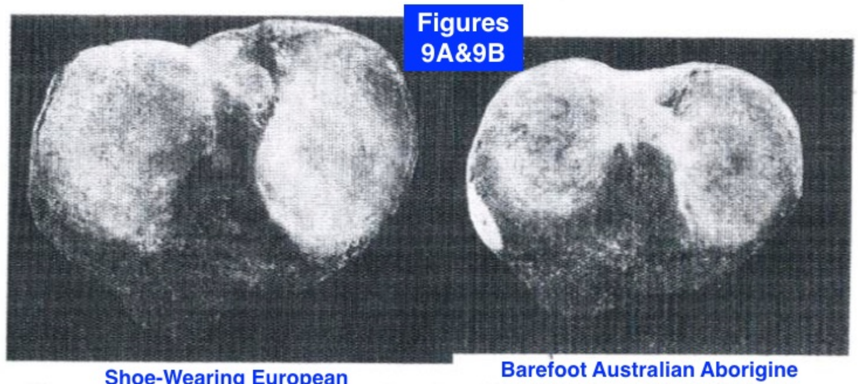
During a lifetime, the biomechanical effect of shoe heels artificially changes the actual physical structure of human bones and the joints connecting them. Those structures have always been assumed to be anatomically natural, but are in fact pathologically abnormal.

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

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 reduced pressure on the outside or lateral portion

That abnormal and extreme stress causes an unnatural restructuring of the knee while tilted out. The tilting creates an unnatural rotary motion, unbalancing 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 former runners due to knee pain, and of those, many become non-walkers due to knee arthritis caused by their deformed knees.

As you can see in the left section of the photograph in **FIGURE 9A**, the modern European knee has an abnormal rotary motion (in the horizontal plane) molded into the bone. The primitive barefoot knee of an Australian aborigine shown in the right section **FIGURE 9B** is natural and therefore does not show any evidence of rotary motion. Primitive barefoot knees of Caucasians of India, as well as ancient Romans, also look like that of the Australian aborigine.[14]



The proximal aspects of a European and an Australian tibia of approximately the same length. The greater breadth and more massive character of the European epiphysis are clearly demonstrated. The two bones were photographed at the same distance from the camera.

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. It shows an internal and external rotation range of horizontal motion of the knee during the stance phase of running of about **8°**, and 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 in terms of an abnormal grinding motion, like mill stones grinding wheat, except that it is the surfaces of your knee that are doing the grinding. The obvious conclusion is this unnatural rotary grinding action at least accelerates or causes knee osteoarthritis, its most common modern form.

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

Like the modern rotary knee, the modern ankle bone shown in **FIGURE 9D** shows the same rotary motion induced enlargement, compared to the primitive barefoot Egyptian ankle bone shown in **FIGURE 9C**.

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

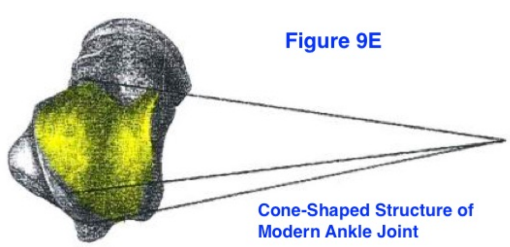
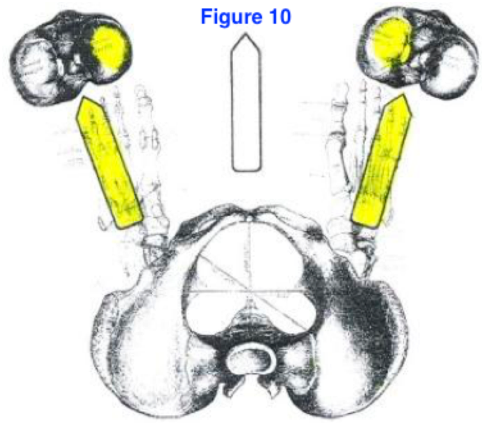


FIGURE 9E shows more definitively the well-known but unnatural rotary structure built into the modern ankle joint (ankle joint trochlear surfaces highlighted in yellow).

Both the ankle joint axis and the subtalar joint axis (that control the coupling relationship discussed above) are likely moved into abnormal orientations by the structural bone changes made artificially by elevated shoes heels.

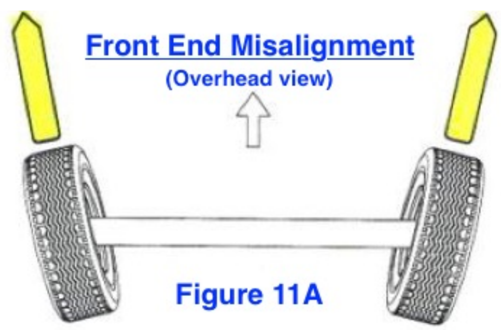
Both Ankle Joints Point Unnaturally to the Outside, Not Straight Ahead

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 10**, the ankle joint of the right foot is twisted outward to the right, and the ankle joint of the left foot is twisted outward to the left; both instead of straight ahead. Consequently, both knees are also forced to the outside unnaturally, with most of the body weight load shifted to the inside (medial) half of the knee (in yellow).

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

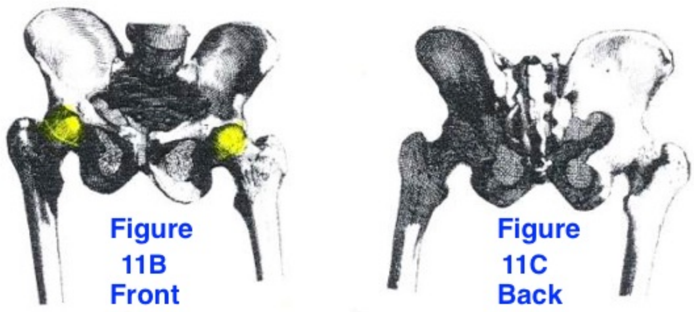


Imagine for a minute this crude car analogy, where your legs and pelvis are the front end of the car. Your legs are the wheels and suspension, and your pelvis is the rest of the front end of a car. Because of elevated shoe heels, your front end is not correctly aligned, to put it mildly. It is splayed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

In effect, each wheel has over-inflated tires, making them like your abnormally supinated foot (which is unnaturally rigid) and is also tilted-out to wear on the outside edge of the tire, like your supinated foot (which is tilted to the outside). In addition, each wheel is pointed in a different direction to the outside, not straight ahead. See the overhead view in **FIGURE 11A**.

It is easy to forecast what will happen. 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 mechanical 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 accommodative biological machine. But the result is the same in the end, even if the cause and effect relationship is less obvious. Just a slower, subtler breakdown over a much longer period of time.



In short, then, elevated shoe heels create abnormal body structures that cannot work together as a complex, interrelated biomechanical system in a natural way. They can only cause an early, unnatural breakdown, both more rapidly and in abnormal ways.

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

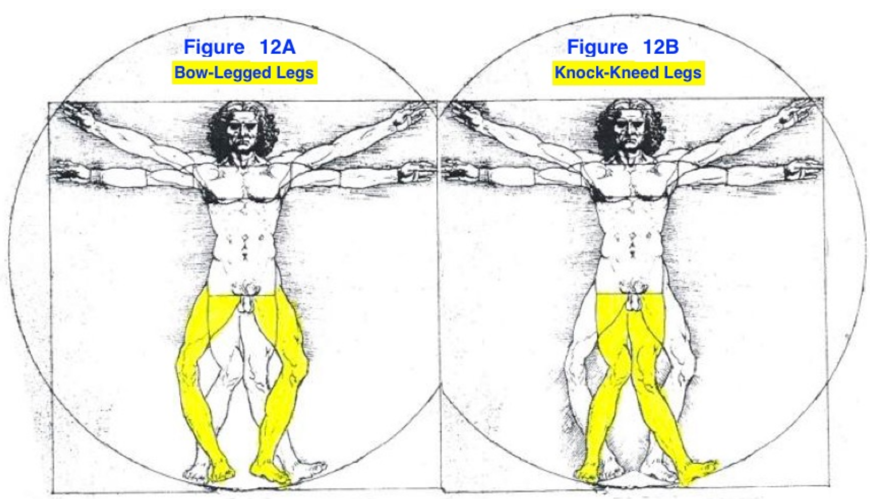
It should be noted as well that the actual structural orientation of the natural, un-deformed hip joint is not optimized for standing fully upright and walking (as typically shown above). Instead, the hip joint orientation is optimized for running in a flexed position, because that is when it is maximally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

Until now, the exposed position of the hip joint has been thought incorrectly to have resulted from incomplete human evolution to bipedal from quadrupedal locomotion. In other words, the evolution from **90º** leg flex to **0º** straight has been assumed to be unfinished. Whereas actually evolution is fully complete at roughly **45º** leg flex, which is exactly optimal for the max load running position shown in **FIGURE 7**.

The Basic Alignment of Human Legs Is Altered by Shoe Heels

Structural instability inherently directly affects everyone that typically wears shoe heels, but each individual adapts in their own particular way. Many factors are in play, including unlucky injuries, but generally those 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.

<u>Two Major Types of Leg Deformity in the Modern Human Body</u>



Those generally with more flexible subtalar joint and foot arches rotate inward in pronation in reaction to the unnatural horizontal component vector, which causes their legs to bend inward into **knock-kneed** positions. See **FIGURE 12B**.

What is truly odd here is that both positions - bow-legged and knock-kneed - are opposites, yet both result directly from the same thing: the inherently unstable position caused by shoe heels, as illustrated previously in **FIGURES 8 C&D**.

So, the inherent instability of shoe heels creates an unnaturally wide spectrum of individual adaptations to compensate. A lucky few are precariously balanced in the middle with vertically aligned legs, but the rest are not, and many have greatly exaggerated misalignment.

One of the most surprising results is that bodies of most men and women are made much more different and in an unnatural way. Most **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. Called varus knee thrust, it weakens their legs and makes them poorer jumpers.

The unnatural twisting mechanism is the same in women, but in contrast, most **women tend to become the opposite, knock-kneed**, as shown above in **FIGURE 12B**. This is primarily because of their frequent use of much higher heels, effectively wider pelvis (due to relatively shorter thigh bones), and greater joint flexibility –all of which cause their legs to rotate inward.

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

As shown in **FIGURE 13A**, the illiotibial tract is a long ligament connecting the pelvic crest to the upper, outside edge of the tibia. It forces the pelvis to rotate backwards when the tibia rotates outward, when the foot supinates, including the supination caused by elevated shoe heels (as shown previously in **FIGURE 6 B**).

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

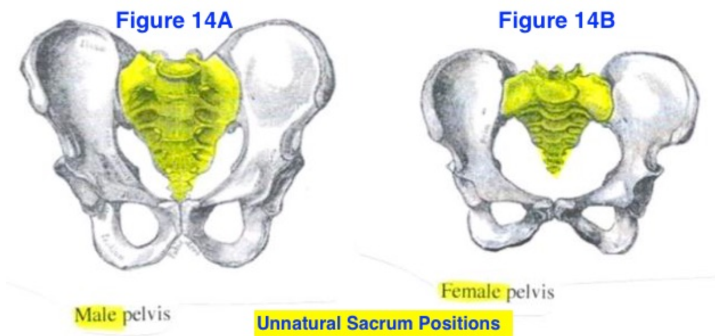
The Natural Differences of Male and Female Are Unnaturally Exaggerated by Shoe Heels Due to the Illiotibial Tract Mechanism

The male pelvis is typically flattened and automatically **rotated backward**, as shown above in **FIGURE 13B**, because of its mechanical connection to the outward twisted knee by a critical ligament, the illiotibial tract. That rotation flattens the male lower back and male butt, and softens the belly.

The female pelvis is also first flattened, but then **rotated forward** in additional compensation, as shown above in **FIGURE 13C**, resulting in an excessive rounding of the female lower back and butt, making pregnancy and childbirth unnaturally difficult.

The Base of the 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. It is rotated abnormally backwards in the male (on left in **FIGURE 13B**) and abnormally forward in the female (on right in **FIGURE 13C**). Each is in a different and unnatural position to provide direct support the spine above it.



The unnaturally different supporting positions of the sacrum shown above force the curvature of the spine typically to decrease in modern men, shown in **FIGURE 15 B** below, making the abnormal modern male spine inherently more static.

In contrast, the abnormal curvature of the spine is typically increased in modern women, shown in **FIGURE 15 A** below, making it inherently more dynamic. 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, sexual performance, satisfaction, and fertility are all reduced for both sexes by the unnatural asymmetrical mismatch in pelvic position and abnormal pelvic functional ability. Shown below **FIGURE 15C** is extreme example of the effect of pelvic asymmetry on modern male genitalia.

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

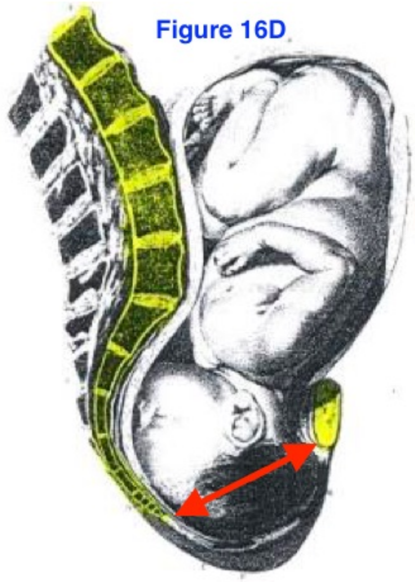
Huge Skull

Figure 16A

Childbirth Is Made Dangerous by the Warped Shape of Female Pelvic Birth Canal

The main problem in human childbirth is the size and shape of a human 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 it makes the skeleton look like 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**.

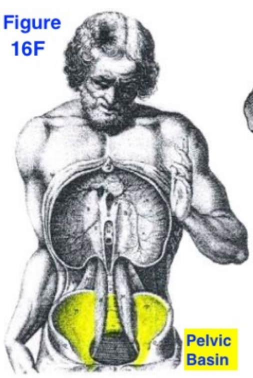
The bone of the female pelvic brim and the baby's relatively huge skull are about the same size (see **FIGURE 16B**). So, the fit is far tighter than other primates. But mismatched in shape also, so that the baby must enter the birth canal sideways, and then make a difficult 90° turn, all because of the unnaturally flattened, mishapen brim and pelvis (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**. However, that inherently difficult birth passage is the most traumatic event to which the fetus's brain is exposed, so the danger to it is great and any damage can have severe aftereffects extending throughout later life.

Moreover, as shown on bottom right in the last drawing in **FIGURE 16E**, the unnatural asymmetry of the mother's body can affect the way the fetus is carried within the womb for its nine-month development period. The fetus' position may be unnaturally asymmetrical, for example, affecting its development unnaturally, both before and after birth.

Critical to our understanding of the misalignment problem is that the word "pelvis" is Latin for basin. See **FIGURE 16F**. That basin is piled high with our internal organs. See **FIGURE 16G**.



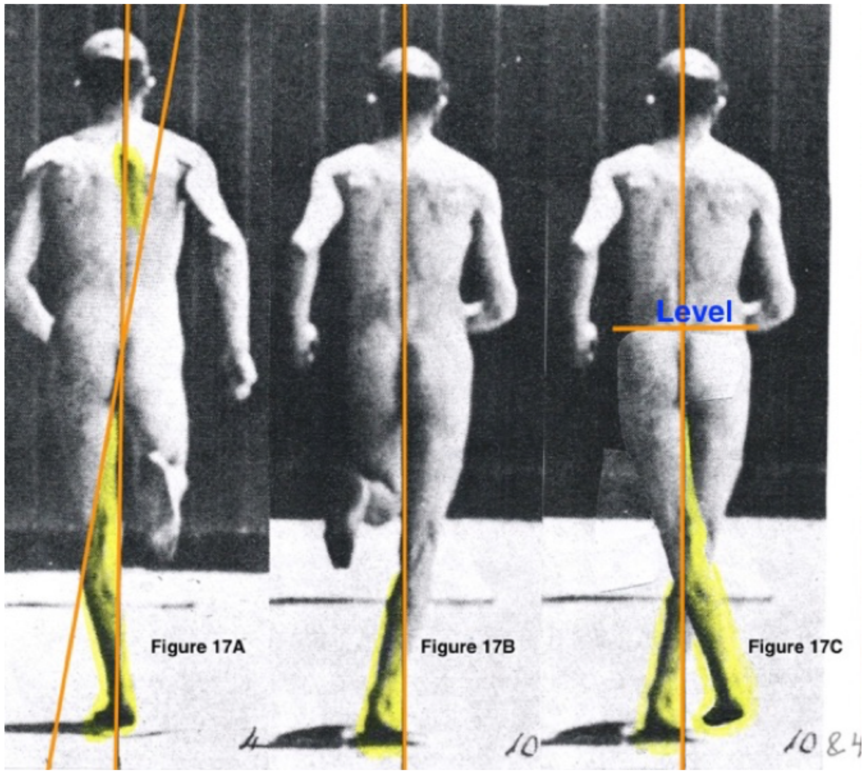
It would seem likely that tilting that basin into an abnormal backwards or forwards orientation would likely shift our intestines and bladder out of their natural positions, slowing down or even temporarily blocking passage of their contents. Heartburn, indigestion, gas, constipation, diarrhea, hemorrhoids, and incontinence are likely direct effects of the abnormal position of the digestive system. Sexual organs are similarly displaced.

All of the other internal systems either contained by and/or supported by the pelvis would likely be similarly affected as well. The other major and minor organs have a multitude of interconnections and interactions that are amazingly complicated and often quite delicate. The function of these organs and 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 pelvises of both sexes tending to be abnormally tilted down on one or both sides, and also twisted into an asymmetrical position.

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



Typical but Bizarre Running Leg Positions at Maximum Flex and Load

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 Legs At Midstance

The award-winning Willwacher et al. study[11] generally confirms the above results, although it has data only on the right leg and 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** above with <u>no</u> crossover and vertical legs with level, un-tilted pelvis. Also note his straight, well-defined spine.

Both Legs Together Form an Immobilizing X-shape Relative to the 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 how truly bizarre is the abnormal structural running position of the modern human body. Remember, this is the maximal load-bearing position, 2-3 times bodyweight, the greatest stress to which the human body is routinely subjected during the childhood growth phase.

This is astonishing! In every stride, the runner's legs are maximally loaded sequentially in a bizarre X-shaped, crossed position relative to the pelvis.

As seen in **FIGURES 17 A&B**, the **unnatural mechanical tilting out effect of shoe heels on both legs paradoxically causes both legs to tilt inward instead, called hip adduction**.

That contradictory result is because both legs are connected 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.

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

Again, from unpublished data 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.

But, at the beginning of the stance phase in running, the starting hip angle for the **males** is immediately **8°** of **ad**duction (tilting-**in**), not abduction. This is an extraordinary change, a full **11°** of tilting-**in**ward, 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, a full **12°** tilting-**in**ward from standing to running on the female support leg.

In **FIGURE 17E** Kenenisa Bekele of Ethiopia is shown finishing the second fastest marathon in history (2 hours, 3 minutes, 3 seconds) with vertical legs and no crossover, demonstrating the biomechanical racing advantage of growing up running barefoot (the primary reason for the almost total dominance of distance racing by Africans, especially from Kenya and Ethiopia).

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 pretty well summarized in the drawings below. Both legs are tilted so far in by the mechanical action of shoe heels that they cross over each other (shown in line drawing of **FIGURE 18A** on the left). So, the only way for the human body to move forward without tripping over its own legs is for one side of the pelvis to tilt down, so the feet no longer cross over (shown in line drawing of **FIGURE 18A** on the right). The functionally short leg is loadbearing and the longer leg is non-loadbearing, enabling forward motion.

That is shown in the male running in the previous **FIGURES 17 A&B** photographs above. To move forward, his left pelvis tilts down, which effectively reduces the inward tilt of his left leg. His right leg tilts in more and crosses over under his center of gravity, while his pelvis is level. This is the most common male resolution to the major structural misalignment.

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

The typical female solution to the problem is different from the male. Due to their higher heels, wider pelvises and shorter femurs, and more flexible joints, the most common female resolution to the misalignment problem is to tilt the pelvis down on each side alternately (shown walking in **FIGURE 18B**).

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 during walking (compared to running). Modern female crossover is even greater than modern male crossover.

However, female legs typically appear to be more vertical relative to the ground and positioned more directly under the body's center of gravity (roughly at the small of the back), but almost exclusively because of the severe pelvic tilting

So, the obvious conclusion is that the underlying reason high heels are so popular with both women and men is that they automatically require massive female pelvic tilting gyrations in order to simply move forward when walking.

In **FIGURE 18C**, a barefoot "primitive" Asian ("Napalm Girl" Kim Phuc) has an aligned body with no leg or spinal crossover or pelvic tilt when running straight ahead.

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

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

The Force Behind This Abnormal Pelvic Tilting Is Overpowering

Back to running, because there is an extremely important point to be made here. 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 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 much greater relative force causing hip adduction than knee adduction and far more than that causing ankle eversion.

And it is critical to understand that this overpowering torque is really forcing pelvic tilt downward, not hip adduction inward (i.e. tilting the thigh bone inward). Of course, in either case, the hip joint action brings the pelvis and thigh bone together in exactly the same way relative to each other.

But if the pelvis tilts downward, 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, the low leg on the tilted down side of the pelvis is flexed upward and unloaded, airborne during running or walking, so it is tucked out of the way.)

The inertia of the main body mass supported by the pelvis preempts the possibility of the substantial side-to-side motion that would be required by hip adduction forcing the support leg to tilt in. Instead, the main body mass overpoweringly forces the pelvis to tilt down toward the supporting leg, thereby straightening it and allowing the running body to move forward in the most energy efficient way. Otherwise, incapacitating crossover occurs between the legs.

Both pelvic tilt and crossover are unnatural and 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 each of both ankle, knee, and hip joints on both legs is affected to some extent.

The Dramatic Differences of Barefoot and Modern Bodies During Running

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

In contrast on the right above in **FIGURE 19B**, you see the bowed-out leg pointed outward, tilted pelvis, deformed spine and back (with vertebrae protruding unnaturally between the shoulder blades), and head tilted to the right – all typical of the shoe heel-deformed modern body (a Finnish marathoner), also shown running in about the same midstance position.

(From a fairly recent (May 26, 2013) video clip on **YouTube** titled "**Barefoot running Bushman versus me (shod Finn)**" https://www.youtube.com/watch?v=H1Ej2Qxv0W8.)

Similarly, the only **YouTube** video clip I could locate of a native Western barefoot runner was of Zola Budd. It is titled "**Zola Budd 'world record' 2000 metres**" https://www.youtube.com/watch?v=FGSjpUIGbZs.

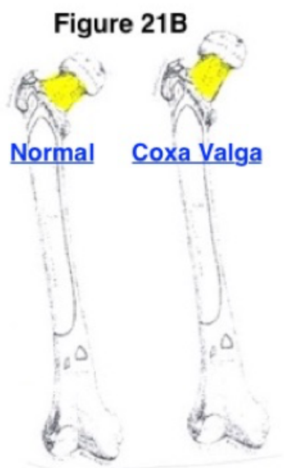
Unfortunately, the 1980's era video is of very poor quality. The best still photo I could extract is **FIGURE 20**, which at least does seem to indicate a very straight leg/level pelvis style by Zola in comparison to the modern Western runner slightly behind her.

Again, new field work is necessary to video barefoot Western/Caucasian runners who have never worn shoes, perhaps some can be located in the South Pacific. Alternatively, many of the population of India are Caucasian and have been barefoot throughout life, although most of those affluent enough to be "runners" have had extensive exposure to 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 19** shows the early stages of the same kind of structural deformities that progress to a much more exaggerated and permanent state in a disease called scoliosis, shown in **FIGURE 21A**, the photograph below.

In fact, scoliosis is just an extreme case for what passes for "normal" in the abnormal modern human body. The same kind unnatural asymmetrical spine twisting is present to a greater or lesser degree in most modern bodies because of twisting effect of shoe heels. 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.[12]



The widespread epidemic of back pain is the direct result, affecting nearly 30% of all U.S. adults each year. Sometimes unusually fit adults like NBA Warriors Coach Steve Kerr and Golfer Tiger Woods are still incapacitated even years after back surgery.

In addition, the femur neck inclination called coxa valga in which the angle of the femur neck is greater than 125 degrees is associated with scoliosis. See the coxa valga femur on right in **FIGURE 21B**. It is also associated with hip adduction like the abnormally exaggerated hip adduction in running shown in **FIGURES 17C & 18B**.

This suggests the probability 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, like that shown in **FIGURE 18B**.

Moreover, being unable to run in safety, the blind therefore do not get scoliosis (or at least did not during the period before guide runners became an option fairly recently).

The Twisted Posture of Young Modern Runners Looks Like Elderly Stoop

Although severe scoliosis is relatively rare, the effect of age on posture looks very similar and is directly caused by the effects of shoe heels. See **FIGURES 22 A&B** and note particularly the typically crossed legs like **FIGURES 17C & 18A&B** obviously a direct effect of shoe heel-induced supination and resulting knee cant discussed earlier.

Substantial Asymmetry Is Universal in the Abnormal Modern Human Body

Heretofore, all biomechanical studies of the lower extremity during running test only one leg, but a precedent-breaking 2017 study[12] by Radzak at al. specifically collected data on both right and left legs to evaluate asymmetry during running. The differences they found were astonishingly large.

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°**.

So, when running, most runners 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 foot and ankle of most runners will be lower than the right foot and ankle. This height difference creates a lower left leg and higher right leg during running. That abnormal leg length asymmetry biomechanically creates in turn an unnaturally asymmetric pelvic tilt.

Similarly, 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, less than half as much.

The reported hip joint differences 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 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 study[12] 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

Racial Differences Are Also Exaggerated by Shoe Heels

Just like sex differences, racial differences are abnormally exaggerated by shoe heels. Besides the feet shown in **FIGURE 1B,** most other differences between the modern European human body and that of “primitive” races (who happen to also be barefoot) are also directly caused by shoe heels. This conclusion is also supported by recent genetic studies which underline how close genetically all modern humans are, due to their small pool of ancestors in just the last few thousand years.[17]

In the unique example below (again from a relatively old and obscure, but authoritative medical source), the same individual Caucasian male demonstrates that the simple realignment of his legs from knock-kneed **FIGURE 23A** (more typical of African descent with low longitudinal arch or pronated feet) to bow-legged **FIGURE 23B** (more typical of Caucasian with high longitudinal arch or supinated feet).

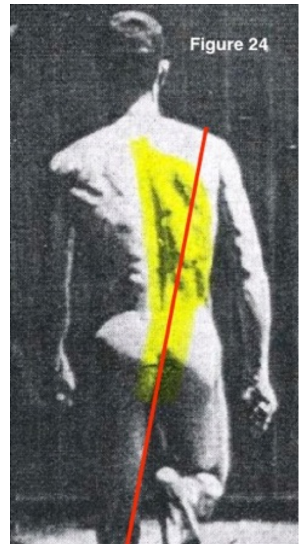
That simple angular re-aligment drastically changes the resulting thigh musculature along the same typical racial lines. The racially distinctive leg musculature is clearly determined only by varus/valgus leg angular alignment related to foot arch height, not by race, as clearly shown by **FIGURES 23A&B**.

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.[18]

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

As noted in Endnote[11], individuals with lower longitudinal arches **(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 reduces the amount of rotary torsion built into the structure of the modern knee joint of low arched individuals, so that it is more like the "primitive" natural barefoot knee joint in **FIGURE 9B** instead of **FIGURE 9A**.

The Precursor of Heart Disease?



Abnormal Chest Distortion Causes Unnatural Pressure on Heart

The misalignment deformities of old age start early in life from running. The torsional distortions in the chest area are often substantial, as seen in **FIGURE 24,** likely leading to unnatural pressure on the heart and eventually heart disease.

The distortions appear to be greater on the right side, which may be generally protective to the left side-oriented heart. However, since the pelvis is tilted-down substantially to the right, the spine is actually curved far to the left side relative to the pelvis, so the abnormal torque and excessive pressure may focus directly on the heart. That unnaturally distorts and stresses the heart, at the point in the running stride when the body is subjected to peak body weight.

Previous **FIGURE 17A** shows the same unnatural chest distortion and pelvic tilt, and in addition at the same time includes the **20°** inward tilt of the left leg, increasing the extent of overall structural abnormality.

Natural Human Performance Has Much Higher Limits

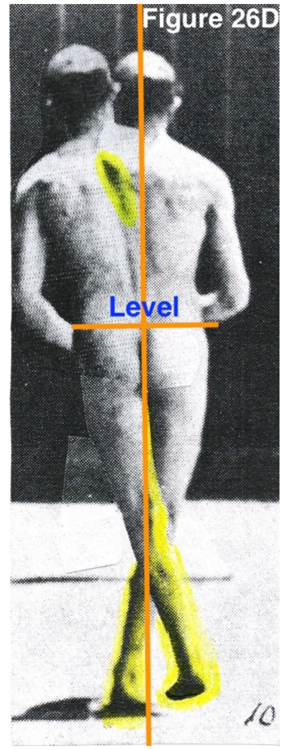
What we now regard as highly exceptional is much closer to the natural norm of human potential. We only fail to realize this because of our current deformities anchor us well within unnatural limits. To give you another example of what I am trying to say, see this picture in **FIGURE 25** of the limbo king of New York City performing in the 1960's. This picture demonstrates an almost unbelievable performance extreme. But all of us have the 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 Skull and Brain: Just Like the Knee

The body part that most unexpectedly appears to have been affected by elevated shoe heels is the part farthest away from the heels: the human brain. This is because the abnormal effects are exaggerated in the motion of the head while running with shoe heels (**FIGURE 26A**).

Famous photos of Jim Ryun (**FIGURE 26B**) and Roger Bannister (**FIGURE 26C**) setting world records in the mile both indicate abnormal head motion that is similarly exaggerated. While these head motions may seem extreme but also very occasional, they are just exaggerated examples of common abnormal motion of a reduced but still significant and endlessly repetitive routine nature (**FIGURE 26A**).

FIGURE 26D shows how the upper torso is whipsawed back and forth between each tilted-in leg at the point of maximum load during running, relative to a level pelvis. This unnatural whipsawing motion is 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 running, whereas it is upright at midstance on the other leg. This is an amazing amount of left/right asymmetry given his almost superhuman level of athletic performance.

It suggests that such skull position asymmetry or more is widespread throughout the human population, although it is apparently never studied in biomechanics studies on running. For example, even the unusually comprehensive study by Radzak et al. noted above,[12] which uses 27 reflective markers all over both sides of the test subject's body, has no markers on the cervical spine nor on the skull.

Bolt's high degree of asymmetry also suggests that his seemingly superhuman level of sprint performance is probably not near the maximum limit of human potential. His asymmetry is probably due to his use of conventional athletic shoes after a barefoot childhood in Jamaica.

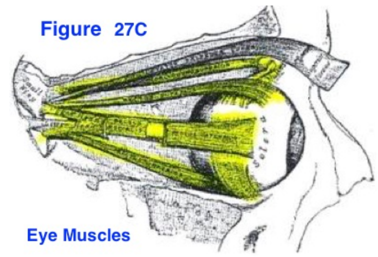
The typical leftward tilt of the Bolt's head during running midstance (shown on alternating legs) must over time alter the permanent structure of the cervical vertebrae of the neck, causing them to bow out in compensation to the asymmetrical position and load, like the typical example (not Bolt) shown in **FIGURE 27B.**

As seen in **FIGURE 27B**, this asymmetrical position of the cervical vertebrae bowing out to the right to compensate for leftward tilt of the modern skull thus becomes quite evident even at rest in a stationary position. Arterial hyper-development on the right side also 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.

Vision Illustrates the Structural and Functional Problems Within the Abnormally Supported Skull

Just consider vision as a fairly simple example. The most common modern problem is near-sightedness (myopia), which results from an abnormal elongation of the eye.

If the skull is typically bent backwards as noted by the excessive curve of the cervical spine, then the new, more downwardly directed force of gravity is going to increase pressure on the back of the eye. That gradually tends to lengthen it over time (and continues over time), moving the retina at the back of the eye backwards and increasingly out of focus. If the skull is bent sideways too, then that creates asymmetry between the right and left eyes. Add in twisting motion as well, so the abnormal skull motion is in all three dimensions. The result is asymmetry within either or both eyes (astigmatism), and well as different levels of myopia in each eye. As shown in **FIGURE 27C**, note the complex and delicate structural arrangement of the muscles controlling the eye,



Similar mechanisms are at play for the all the other deficits inside and outside the skull that were listed above. Of course, as usual, there are no known direct causes for any of these listed head-centric problems. By default, the accepted current wisdom is that they all just happen; for example, poor eyesight probably caused by eyestrain from too much reading.

The Asymmetrical Structure of the Modern Brain Shows the Same Abnormal Rotary Torque as the Unnatural Modern Knee

The brain has been made much more bilaterally asymmetrical by elevated shoe heels, as has all of the human body. Incredibly, it is well established in modern neuroscience 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 **FIGURES 9A&B**.

The functional effect of this abnormal structure is that the brain appears to have been enhanced in its highest level of mental functions, which are 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 the highest mental functions.

Albert Einstein's Asymmetrical and Brilliant Brain

A typical but extraordinary supporting example is seen in Albert **Einstein's brain**. As shown in a top view in **FIGURE 28A**, Einstein's brain was **asymmetrical**, with unnatural rotary torque squeezing the right hemisphere forward and compressing it relative to the wider left hemisphere (in yellow), which has expanded into a greater maximum diameter (crossing over brain centerline), with the increase in the size located in the areas of the critical left hemisphere's dorsolateral prefrontal cortex.

In contrast, **FIGURE 28B** shows the earliest (1844) detailed drawing of a top view of a human brain, by A. L. F. Foville, a French physican.[19] Unlike Einstein's brain, Foville's drawing shows a presumably **pre-modern, natural brain** with symmetrical hemispheres and no apparent indication of any rotary torque.

Of course, it is unknowable whether that brain is truly a "barefoot" brain reflecting the absence of elevated shoe heel use. However, it is a fact that after the French Revolution of 1789, elevated heel use fell into an extended period of general disfavor, since it was stylistically emblematic of the excesses of the corrupt French nobility. Moreover, most dissections were done on bodies from the lowest classes, which were the least likely to have ever worn stylish shoes with elevated heels.

The very first detailed drawing of a human brain is the first drawing in a neuroanatomy book published 1664 by Thomas Willis, an Englishman who is considered the founder of modern clinical neuroscience and comparative neuroanatomy.[20] That drawing is included here as **FIGURE 28C** (and, interestingly, it is attributed to **Christopher Wren**, the architect who famously designed Saint Paul's Cathedral in London).

The Wren drawing shows a bottom view of the base of a human brain, completed 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**.

Unlike Einstein's brain, the Wren brain drawing shows no forward shift of the right hemisphere. Instead, it shows a very slight forward shift of the other hemisphere, the left hemisphere. So, if there is any rotary torque at all, it is minor and in the opposite direction from that shown in Einstein's brain.

However, like Einstein's brain, the Wren brain drawing does show enlargement of the relative size of the left hemisphere, although less than Einstein's. This lessor size asymmetry may be a simple function of prevalence in humans of right handedness, the right side of the human body being controlled by the left hemisphere of the brain. If so, then the evolutionary development of human bipedalism, which enabled the development of tool and weapon use, particularly of the right hand and arm, probably led to an initial, partial stage in the structural development of the modern human brain.

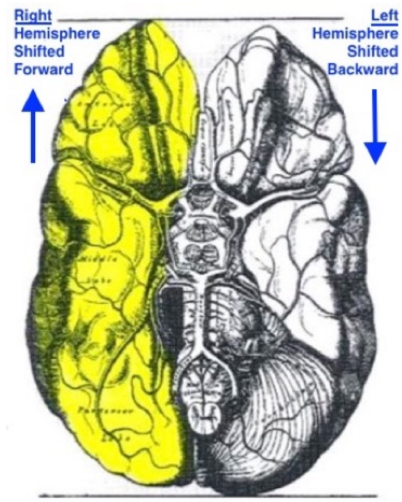


Fig. 28D - Gray's Modern Brain

Finally, another typical example of the obvious rotary torsion of the **modern English brain** is available in **FIGURE 28D** from the 1858 Edition of ***Gray's Anatomy***.

Unfortunately, the very small preceding sample of drawings of the pre-modern, natural human brain are the only evidence of its structure available in published literature. The fact that the Wren drawing of 1664 was the first detailed drawing of the human brain and the Foville Drawing of 1844 only the second – with an interval of nearly two centuries between them – speaks volumes about how little detailed brain evidence exists in the public record.

And, of course, the accuracy of any of the above referenced brain drawings is unknown. Nor is there more conclusive photographic or physical evidence like that from the Einstein brain, for example. Therefore, the definitive structure of the pre-modern, natural human brain is not currently known with certainty. However, such evidence should be readily obtainable through the examination of living and deceased members of the few remaining primitive "barefoot" populations using modern technology, including MRI and other scanning techniques.

Steven Hawkings' Brilliant Brain and Asymmetrical Body Due to ALS

Steven Hawkings' exceptional brain is likely to be similarly asymmetrical, due to his ALS (amyotrophic lateral sclerosis or Lou Gehrig's disease), which has forced his entire body into a deformed structure much like that of scoliosis, as seen above in **FIGURES 29A**, but even more extreme.

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

The Renaissance and Reformation, and The Rise of Modern Science and Technology

The substantial physical asymmetries of Einstein and Hawkings suggest a correlation with exceptional intellectual ability. Remarkably, elevated shoe heels were introduced into use in Western Europe during the same historical period as the very beginning of modern science and technology that created the modern world.

Elevated shoe heels therefore may have - in a totally inadvertent way - provided a brain boost that ignited the revolutionary explosion of technological invention and progress that occurred then. Although that direct causation seems almost unimaginable, given the utter innocuousness of shoe heels, it is an unavoidable logical possibility. It is shockingly plausible that elevated shoe heels created the modern geek.

The Major Downside of Unnatural Brain Asymmetry: Dementia

An excellent TED Talk titled *Why Helmets don't prevent concussions – and what might* by David Camarillo, Ph.D. of Stanford University was made April 24, 2016 (see www.ted.com). Dr. Camarillo provides good evidence that the conventional understanding of brain concussion and related dementia is fundamentally wrong.

The true problem is that 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 simulation.

It turns out the location of that maximally stretched portion is particularly unfortunate, because it is the precise location of the principal network connection between the right and left hemispheres of the brain. The physical brain structure located there is the **corpus callosum**, circled in red as shown in the normal brain in **FIGURE 31**.

In an abnormal brain subject to repeated concussions shown below in **FIGURE 32**, which is that of a retired former NFL football player who suffered from chronic traumatic encephalopathy (CTE), the corpus callosum is severely deteriorated, indeed much more deteriorated than any other portion of the brain.

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

It seems logical to conclude that if extreme traumatic forces cause excessively violent sideways motion leading to acute injury like concussions and CTE, then highly repetitive abnormal sideways motion caused by shoe heels in running is likely to cause repetitive stress injuries to the brain, albeit very gradually over time. That would be particularly true over a very long period like a lifetime, the unnatural effects being cumulative.

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

So, it seems reasonable to conclude that there is a strong possibility, perhaps even a probability, that the same injury mechanism that is apparent in concussion on an acute basis also adversely affects the brain on a chronic basis due to repetitive stress. This line of thinking suggests the obvious possibility that dementia may generally be a repetitive stress injury to brain tissue caused by artificial shoe heel-induced unnatural torques resulting in body and brain asymmetry.

The latest research on CTE even suggests that this repetitive stress may be the ultimate cause of CTE itself as well. According to Dr. Ann McKee, the neuropathogist director of 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 over many years (especially a long professional career) that is the underlying problem and the most significant factor.

If this is correct, then CTE is either caused or aggravated by the abnormally fragile human body, made so structurally and functionally by the repetitive abnormal torsion effect of shoe heels over a lifetime.

Alzheimer's Disease

Even the plaque in the brain tissue of Alzheimer's patients may be due to the unnatural stretching from 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 causing diseases like osteoporosis, deafness, atherosclerosis, cancer, osteoarthritis, muscular dystrophies, and developmental disorders.[21]

In the brain, with its jello-like consistency the disruption effect is potentially worse than in other parts of the body. The roughly 85 billion neurons in the brain are structurally supported by glial cells and the neurons are connected to other neurons by about 100 trillion branches that terminate in about 100 trillion synapses – all extremely fragile structures likely degraded by unnatural cellular repetitive stretching.

Moreover, a review of the available evidence indicates a close relationship between cognitive disorders and gait disorders.[22] So, based on the preceding discussion, gait disorders wrought by shoe heels may possibly or even probably predate the cognitive disorders and actually cause them.

Other Mental Diseases

Ironically enough, a very reasonable case can be made that many or even most forms of mental illness may also be either caused and/or aggravated by shoe heels in the manner describe above. A recent study has tied concussions in teenagers to a greater risk for developing multiple sclerosis.[23]

In addition, I was told recently by a medical doctor[24] that virtually all of his mental patients at St. Elizabeth's Hospital had splayed feet, meaning that they were twisted to the outside, as happens typically as an excessive pronation compensation to the lower limb misalignment shown previously in **Figure 10**. Also, it is well-known in the literature that mental patients generally have abnormal, even significantly impaired gait.

Although the St. Elizabeth's doctor has always assumed that this splayed foot position was due to the various abnormal mental conditions that occurred with them, that is clearly just an assumption based on simple correlation, not causation. There are absolutely no known causative factors currently.

His simple assumption is that mental abnormalities may cause the physical abnormalities associated with them. This top-down assumption is certainly plausible, but a bottom-up assumption based on what has been previously presented here is far more credible, given the specific causative bio-mechanisms that already have been 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.

So it makes obvious sense that 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, sometimes severely enough to result in mental disease in its many varieties and degrees.

This fact-based explanation is supported, for example, by the earliest description of Parkinson's disease by James Parkinson (1755-1824), with even the overt suggestion of its origin in 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.[25]

First Real Proof That Going Barefoot Is Not the Solution for Most Modern Human Bodies

But the unfortunate reality is that once the physical abnormalities discussed above become well developed, as they do in most individuals, those changes become locked into actual bone structural changes in the foot, ankle, knee, hip, pelvis and spine. Those joints involved become permanently malformed. So just getting rid of elevated shoe heels is not the simple, obvious solution it might otherwise seem to be.

As noted earlier, the footprints clue cited in the old James report in the Preface (**FIGURES 1 A&B**) is all the more powerful as evidence since the footprints were taken with knee bent forward, supported on that single leg alone, so it was taken in roughly the typical midstance running position shown in **FIGURE 7** above (although at only 1 full body weight, rather than 2-3 times typical of running).

Although obvious, it is nonetheless just as significant that those footprints were taken of bare feet. That provides good evidence that normally shod feet continue to roll unnaturally to the outside in the supination position even when bare, as clearly shown in **FIGURE 1B** because the foot and ankle bones, and associated ligaments, muscles and tendons, have been re-formed abnormally by shoe heels.

Therefore, instead of being an easy solution, simply going barefoot instead of correcting those abnormalities makes them worse for most individuals who have grown up wearing shoe heels! All the more perverse, those individuals whose shoe heel-induced deformities are worse than average will have even greater adjustment problems trying to run barefoot.

So those who need help the most are the least likely to get it barefoot. Only those with less of a problem to start with are likely to be able to transition safely to barefoot running.

This is why running shoe design is currently at a dead-end. There is no easy or immediate solution currently available, or even a known solution. Finding a solution for those individuals most in need will be an extraordinarily complex problem.

Smartphone and Cloud Control of Configurable Shoe Sole Structures Will Provide the Solution

Finding a specific solution for each individual's structural problems is impossible with current methods. 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, so that artificial intelligence using machine learning techniques – typically referred to as "deep learning" - can be applied to the big data from many millions of wearers.

As an inventor, I filed U. S. and international patent applications, and received my first U. S. Patent on this 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 on the Internet at my website: **www.AnatomicResearch.com** or at the **USPTO** website, together with five additional 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.

A short time after the first patent above issued, an unsolicited but highly laudatory third-party **YouTube** video complete with animation on my newly issued patent was discovered inadvertently in an Internet search. 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 smart shoe and phone technology is that it empowers millions of users to become active **citizen scientists**. They can contribute the critical mass data needed to provide the basis for the most effective solutions to asymmetric biomechanical imbalances, while being provided a real-time user window into the entire process via the smartphone, empowering the user to retain overall control of their own personal system.[26]

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

There is however a major roadblock to the indispensable new approach described above. There exists no way to safely create and store this extremely 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 similarly lack reliable protection, as do all other computers, including the cloud.

The seemingly insurmountable problem is that reliable cybersecurity does not currently exist and is not even theoretically possible using existing methods, all based on software. But a basic change at the most fundamental possible level of hardware architecture can provide a practical, foolproof solution to this otherwise intractable problem.

More on this problem and solution in Chapter 34 of my draft book under "Research" at my footwear website: www.AnatomicResearch.com or at my computer security architecture website: www.GloNetComp.com.

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

Unfortunately, it will take time for this technology to be developed and made commercially available on a widespread basis. This is likely to take several years.

In the immediate future, the only relief in sight does not involve footwear. Instead, new forms of stretching and exercise are in the process of being developed and tested.

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

Demonstration videos will be posted on my website, www.AnatomicResearch.com, as soon as available.

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

And/or, second, alternate between running on one day, with strength building and stretching on the other day. You should aim for equal amounts of running and strength building/stretching.

Obviously, some other non-running aerobic exercise can also be added into mix, as well as variable direction running sports like soccer, basketball, tennis, etc.

What Approach to Take in Choosing Between Shoes and Barefeet

Switching between the use of shoe heels and bare feet, especially in rigorous sports and exercise, is itself a likely source of injury. Especially so in the not uncommon example of running barefoot and then wearing conventionally heeled shoes immediately before and after.

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

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

I think this approach is particularly important for women with special regard to high heels, especially spikes. I think you have to come down gradually from these higher heels, especially if you are a serious athlete.

I believe high heels are a particularly serious health problem for women. So many women have such 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 much better choice than high heels (but personally I think that smiling is the most alluring thing you can do).

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

In contrast, for the very young – those whose bodies have never been adversely affected by elevated shoe heels -- the solution is simple. Only for them, their best available physical health option is to go barefoot or wear the most minimal of shoes, those without elevated shoe heels.

Also, for their brain health it is critical that they are allowed adequate exercise every day. As already noted, the brain evolved specifically to make motion possible and coordinating body movement remains its primary function in humans.

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

To Summarize the Effect of Shoe Heels: Broken Bodies, But Better Brains (Although More Delicate and Prone to Dementia and Other Mental Diseases)

In summary, elevated shoe heels have had a terrible effect on the structure and function of every part of the human body – except perhaps the brain, the highest functions of which shoe heels may have enhanced! Overall, a human catastrophe, except for the brain! Even that gain may be more than offset by the loss in the form of more widespread dementia and other mental illnesses.

Gross human anatomy has for a long time been considered the most settled of all the sciences, which is to say that everything of importance has already been discovered, most of it by at least a hundred years ago. However, the opposite is true.

What we have thought for centuries as normal human structure and function is rather an abnormal state of unnatural disease, environmentally caused by elevated shoe heels, which have been all too easy to overlook. As to knowing what is really normal for humans, we are currently limited by the very fragmentary sources of available information.

Massive Medical Expenses

Given its direct bio-mechanical effect on virtually every structural and functional part of the modern human body, the associated medical costs for shoe heels in the U. S. alone could well be as high as $1.5 trillion per year. That translates to something quite absurd, like well over $1,500 in medical costs that accrue for each and every pair of shoes sold each year (assuming $100 average price per pair).

Perhaps even more important, the quality of life provided by elevated shoe heels throughout a lifetime, including from fetus to birth, is drastically reduced in terms of poorer health and well-being throughout life, but especially late in life for the elderly.

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

Today the term "moonshot" is routinely overused. The term is attached to too many unfocused and questionable projects that have no realistic chance of achieving tangible benefits in the foreseeable future.

In this case, however, a true 1960's moonshot-level project to solve the massive medical problems caused by shoe heels is fully justified. That is because in the relatively near term, the real-world benefits on planet Earth would likely dwarf those that were actually gained by going to the moon. There is no other project with anything close to the same "bang for the buck."

The First Step: A Center for Theoretical Human Anatomy

Nearly all of the research that bears on the medical problems described in this article is taking place in a vast number of different and unconnected commercial, academic, medical, and governmental silos, all separated by specialty and/or organization. No one anywhere has anything like a complete picture of the overall problem.

A partial list of organizations that must cooperate effectively to successfully accomplish the required moonshot includes at least a multitude of 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 U.S. and foreign government research and regulatory entities.

A partial list of specialties that similarly must cooperate effectively include all medical care and related research specialties, particularly anatomy, biomechanics, physical anthropology, computer hardware including networks and software, and cybersecurity.

The 1960's moonshot was run by the government, specifically NASA. It resulted in lots of bucks spent, but tangible non-lunar benefits are difficult to identify. And many government-led research projects have been far less effective than the 1960's moonshot, or have even been outright fiascos.[27]

A private non-profit coordinating foundation, a new Center for Theoretical Human Anatomy, with mostly private and some government support can do much better, spending less and achieving much more for humans on planet Earth.

What the Human Anatomy Moonshot can achieve, worldwide, is billions of lives immeasurably improved and/or saved, as well as trillions of dollars in medical expenses saved every year.

Major University Departments Dedicated to the Study of Footwear

As indicated in the foregoing, shoe soles literally form the artificial foundation of the human body, controlling the development of its structure and function. And yet shoe designers have no formal academic training in footwear technology, only on-the-job industry training. They are completely unprepared to be architects of the modern human body. They are utterly blind to the consequences of their work.

There are no meaningful sole design standards or regulatory oversight whatsoever, so widely varying structural products are tested on the public with no practical restraint. Design of shoe lasts, essential to the manufacture of footwear, is generally considered a “black art” understood only by a priestly few.

In utter contrast, building architects are graduated from formal academic programs in well-established universities, numbering over 60 in the U. S. alone and almost 700 worldwide. Associated credentialing, licensing, building codes, and inspection carefully control their architectural products.

So, major new footwear university departments as that critical missing academic foundation should be an essential, permanent part of the Human Anatomy Moonshot.

In addition, vastly more funding is provided today, for example, to neuroscience and to astronomy than to the biomechanical study of the human body in motion, particularly 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-equipped that their research results are of limited practical use, as discussed at length in Endnote[11].

The Major Moonshot Goals

The first goal would be to discover as quickly as possible exactly what is the natural human body: a detailed and accurate understanding of its structure and function, completely unaltered by the effects of footwear, especially elevated shoe heels. Currently it is unknown.

The second goal would be development of the most effective treatment modalities for all those billions of modern humans who unavoidably continue to suffer and die from the vast multitude of adverse effects of past use of shoe heels. Currently not known.

The third goal would be to identify whatever beneficial and/or adverse effects that conventional footwear has specifically on the human brain, and to determine whether such benefits can be maintained or increased without the adverse effects of shoe heels. Also, not currently known.

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 the new technologies 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 is a very modest requirement, since commercial development and use of the patent portfolio will be immensely profitable for these companies and will solve (or reduce as much as possible) huge problems in the existing commercial products upon which they depend.

Private individuals and organizations are needed immediately to provide initial startup funding and infrastructure to jump-start the critical coordination activities of the Center as quickly as possible.

A group of key leading experts must to be pulled out of their disconnected individual specialty silos now to focus together on the big picture. We need an effective working group with the right people to share their knowledge with each other to build the solutions that will make this human anatomy moonshot a success.

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

As shown in detail in the pages above, the elevated shoe heel bio-mechanism has had a massive effect on the structure and function of every part of the modern human body, fundamentally changing it from natural to abnormal, from strong to weak. So, adverse health effects logically should occur throughout the modern human body. It is therefore difficult to imagine any human medical problem that is at least not made worse by the effect of the shoe heel bio-mechanism.

But the effect may be far greater. From arthritis to back pain, from heart disease to sexual dysfunction, even from cancer to constipation – in fact, most non-infectious disease occurring throughout the human body – all currently are disconnected effects which have no known direct cause.

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

Consequently, without specific known causes or underlying aggravating factors, much of modern medical care is forced to resort to trial and error methods to treat the symptoms of disease, instead of directly curing the disease itself, or even preventing the disease in the first place.

This absence of either basic cures or prevention for most major human diseases continues today, despite the vast array of new and amazing medical technologies that are constantly being introduced. The improvements in health care are very real and continual, and save or improve countless lives, but typically are incremental rather than breakthrough cures or prevention.

But incredibly, a strong case is made here for a single unifying contributing factor or possibly even a direct cause for many of these non-infectious diseases. The underlying common problem may be a general overall unnatural physical weakness that results from the specific debilitating effects of unnatural effect shoe heels on the modern human body.

So, even where the biomechanical effect of shoe heels clearly does not directly cause a disease, the effect may substantially weaken the overall human body's ability to function naturally, making the body much more susceptible to infections and unnaturally less able to fight them effectively.

Finally, the effects of shoe heels make the human body far more prone to all types of injury, whether from incidental accidents like ankle sprains or long-term overuse, like repetitive stress injuries.

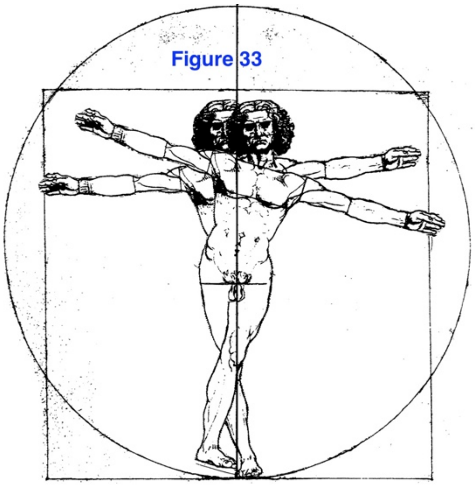
Elevated Shoe Heels Cause a Gross Mismatch Disease

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

The few remaining primitive barefoot hunter-gatherers still in existence are almost immune to most of the noninfectious diseases that kill or disable modern humans, as noted by **Daniel Lieberman** in ***The Story***

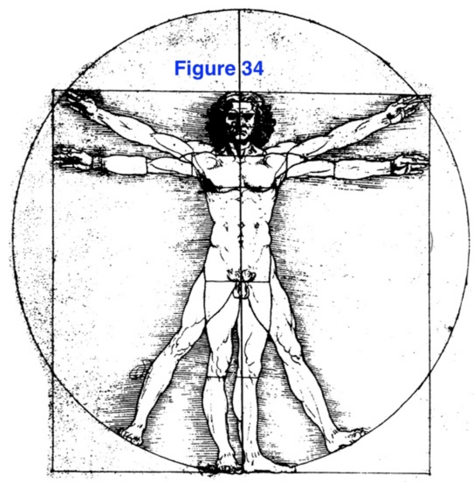
of the Human Body. Liebermann notes that the limited study data available indicates that primitive barefoot middle-aged and elderly hunter-gatherers (who typically live to an age between 68 and 72)

> ...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**.[28] [emphasis added]



The elevated shoe heel bio-mechanism and its improbably powerful and widespread adverse effects constitute a true **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 33**. The deformed modern body has abnormally bent-in legs forcibly tilting an unstable pelvis, resulting in an unnaturally bent-out spine and tilted-in head.



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 norm – the bilaterally symmetrical, theoretically ideal body shown in **FIGURE 34** that existed before elevated shoe heels came into use. It is not the modern human body that has been abnormally deformed and degraded by elevated shoe heels.

Failure Is Not an Option

Far more than the Apollo 13 moon mission is at stake here – including an incalculable number of serious medical problems and even lives at risk – so the mantra that "failure is not an option" must 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 **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 that began first as a fetus in our modern mother's womb (unnaturally formed and less-than-normally functioning), then continued when we took our first infant steps in baby shoes, and continues today.

This book below is a first attempt to discover at least a rough outline of our cage in as much detail as currently possible. It is the first step in finding the fastest and least costly way to escape for each of us.

The Details Are Available in the First Draft of the Book

To recap, it turns out that we do not really know very much about what is anatomically normal for humans. Only very fragmentary sources of good information are currently available.

But we can make educated guesses based on good evidence, as we do in the surprising story that follows in the more detailed first draft of my new book (see it under the tab "**Research**" on my website: www.AnatomicResearch.com.

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.

> ***** My apologies that this **First Draft** is in far less finished form than I would like, but I felt that its early release for expert review is warranted now, as is, obligated by the urgent need to jumpstart an expert debate on the critical medical and anatomical issues raised herein. If correct, as is strongly suggested by the preliminary scientific basis I have provided here, those issues require urgent follow-on research at a far greater scale than I can provide.

ENDNOTES

1. Pardon the offensive language like "native" that was used in this old study, which all too typically uses the racist language of that Colonial era. The study also refers to the "natives" as "savages," probably in shocked reaction to their headhunting and cannibalism, both still common practices in 1939 in the area of New Guinea.

Using slightly more modern terms, the race of the natives would be considered Polynesian and that of the "Europeans" would be Caucasian. To be most correct today, you would just say that the two groups from different geographic areas have discernible genetic differences.

The study is **James**, Clifford S. (1939). Footprints and feet of natives of the Solomon Islands. In the ***Lancet***: 2: 1390-1393. The island in the study, Malaita, is next to Guadalcanal, which just a few years later in 1942 was the site of famous U. S. Marine and Naval battles against the Japanese during World War II.

If you are a bit too skeptical to accept these clues from the very old **James** reference as good enough evidence to continue reading, before quitting please consider this unpublished data recently provided by Dr. Steffen **Willwacher** from his 2015 award-winning running biomechanics study (cited in **Endnote**[11]).

His data says that the static reference angle of ankles is **4** degrees of inversion (virtually identical to supination) for 129 males and **5** degrees of inversion for 93 females -- all middle-aged runners measured while standing in their own shoes.

So Willwacher's recent results generally confirm those of James regarding modern foot supination. Now, let's get back to James.

2. Another old study also shows in **FIGURE 1C** the shoe-wearing European heel bone tilted out in the unnatural supination position, compared to barefoot Africans. Note the level lines of the Achilles tendon attachment to the bone on all three samples, which shows the characteristic supination-based structural tilt to the outside in (D) European versus barefoot Africans (B & C).

Although less complete than the James Solomon Islands study, since it does not show the calcaneus of a European who has never worn shoes, it does show uniquely how the supinated or tilted out position is actually baked into the structure of the bone.

Only the European Heel Bone **(D)** is in the **supinated** position**.**

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 by removing the non-human example (A) a baboon and by colorizing)

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*** *7*th ***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.

9. **Rubin**, Gustav (1971). Tibial Rotation. In ***Bulletin of Prosthetic Research*** - *Spring* 1971, 95-100, especially pages **96-97**.

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.

With regard to Ned's reference 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. These are samples among many other decoupling studies.

The latest and probably 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.)

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

Despite a full-to-overflowing schedule, Ned was kind enough to provide a quick initial analysis of my relatively long and complex first draft of a book (which includes over 50 pages of Endnotes). I believe the most important concern he raised in his review was a **decoupling issue**. Although the static lower leg bio-mechanisms described in **FIGURES 4A&B, 5A&B, 6A&B & 8A** are old and settled science, many studies in recent decades indicate clearly that these well-known static mechanisms are "**de-coupled**" when running, as shown in the studies cited in Endnote[10] above.

I was already aware of many of these studies, but had not specifically addressed the issue in my draft book. In the course of my research I had interpreted the known running decoupling effect to be implicitly supporting an opposite conclusion, but had not formally presented my position explicitly. My personal thanks to Ned for taking the time to raise this important but unresolved issue so it can be directly addressed and emphasized as it should be.

So, in reaction to the issue constructively raised by Ned, I set out to find better support in biomechanics research for my opposing conclusion (to add to the direct support I have already found in reshaped modern bones and joints in **FIGURE 9A&B**). Fortunately, I found it 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.**

What I found was that with some formal analysis the actual physical existence of the artificial decoupling shoe heel bio-mechanism can be proven mathematically using the unusually large data set from the **Willwacher** study**.** The proof is surprisingly solid. It is slightly technical, but you can see a summary of the full analysis below.

Simple Mathematical Proof that Shoe Heel-Induced Foot Supination Causes Joint Decoupling - Provided by Data from the Willwacher Study and Rubin Study

The Rubin study on supination of barefeet found using analogue modeling that for every 1° of supination, the tibia is rotated outward (or externally) by about 1.7°, a ratio of 1:1.72. This is an inherent, automatic linkage that happens strictly by the mechanical simulation of 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).

More precisely, this **direct coupling** between shoe heel-induced subtalar joint supination and tibial outward rotation is strictly bio-mechanical. It is therefore just as inevitable as if it were a direct mechanical interaction of gears. It is strictly automatic.

It is in fact the closest biological equivalent of a strictly mechanical interaction between parts. But, like the automatic mechanical interaction of a multitude of relatively simple geometric parts of a clock, this is an automatic interaction of a much more limited number of human bone parts, all with far more complex, non-geometric anthropomorphic shapes.

The Ankle Angle Frontal Plane graph of Figure 6 of the Willwacher award-winning 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 award-winning 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 an important mystery. Why is the 10° missing? Less than half as much inward tibial rotation occurs in Willwacher's testing when running in shoes compared to Rubin's static testing of barefeet modeling.

The only available explanation is the outward rotation of unnatural supination caused by the shoe heel coupling effect carefully described by Rubin! Simply put, unnatural shoe heels must cause the abnormal joint motion decoupling.

This **10°** discrepancy indicates clear evidence of a very substantial **decoupling** during running in shoes of the directly parallel linkage between ankle and tibia rotation found in Rubin's stationary study of barefeet.

In fact, the substantial decoupling shown in the Willwacher study provides clear proof of the direct mechanical effect of shoe heel-induced supination on knee motion in the transverse plane. The inescapable conclusion is that the shoe heel-induced unnatural supination actually causes the abnormal decoupling, which is otherwise inexplicable (or simply magic), as it has remained until now!

The math is simple. The missing **10°** of inward tibial rotation is a result of **10°** of outward rotation that must be caused (using Rubin's Ratio of 1:1.7) by about **6°** of shoe heel-induced supination, about as expected by our previous analysis of shoe heel-induced supination. The two equal tibia rotations of **10°** in opposite directions cancel each other out, leaving the observed net inward tibia rotation of only **8°** when running in shoes.

No studies currently exist that have measured unloaded foot supination with shoes of varying heel heights in the midstance running position of about **20°** dorsiflexion, so the apparently observed **6°** of shoe heel-induced supination is not validated by other studies. However, the results of many well-established studies have indicated that the unloaded landing position of the foot when running range from about **2°** (Willwacher) to about **8°** (Cavanagh), so the above result of about **6°** is reasonable.

> (Furthermore, as discussed in a few more pages, Willwacher's test subjects are outliers, middle-aged "survivor" runners, not typical runners. So, it is likely that their foot position is closer to neutral than is the norm, making it reasonable to discount his low **2°** result in favor of something closer to the higher **6°** result that we computed from the data.)

Additional support comes from the earlier discussion of **FIGURES 1 A&B**, wherein the standing position Willwacher's test subjects' feet average was **4-5°** of inversion/supination. This measurement was made while standing in their own running shoes, which were unidentified but typically today have heels lifts of about **6-10 mm**.

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

The easiest way to understand this odd result is that, essentially, the runner's foot is pronating in an excessive, additional amount to compensate for the artificial effect of the shoe heel, which has unnaturally rotated the foot outward into an abnormal supination position.

That final result neatly proves mathematically the existence of a direct bio-mechanical decoupling effect of shoe heel-induced ankle joint supination and its directly resulting tibial external rotation, based on the **Willwacher** prize-winning study, which is particularly authoritative because of its exceptionally large and therefore more statistically valid sample size (222 runners) than is typical of running studies!

The abnormally rotary torque built into the upper surface of the shod modern Western knee shown earlier in FIGURE 9A, compared to the primitive barefoot knee in FIGURE 9B, elegantly confirms this as well!

Reservations About This Convenient Mathematical Proof

When I reviewed all the joint coupling running studies cited above in Endnote[10], I noticed that none of them cite Gustav Rubin's static study nor seem to be aware of it. For example, the Stacoff et al. 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 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. Astonishingly, this is exactly the opposite of Rubin's stationary result of nearly two degrees of tibial rotation for every one degree of foot supination (which biomechanically involves nearly the same amount of rearfoot eversion).

The DeLeo et al. 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. Again, roughly the polar opposite of Rubin's result.

The results summarized by DeLeo vary widely, from 1.0 to 2.2, because ankle joint coupling is inherently quite difficult to measure accurately for subjects who are running. In stark contrast, it is very easy to do accurately to develop accurate analogue models for subjects who are stationary, so it is hard to doubt the accuracy of Rubin's results.

This gross mismatch in results should have attracted considerable attention years ago, but apparently has been overlooked because Rubin's study itself has been overlooked. What accounts for the gross mismatch in results? More critically, which one is right?

Problems with the Classic Studies on the Subtalar Joint Axis

The decoupling studies that are cited in Endnote[10] mostly base their reasonable but assumption of a 1:1 ratio of motion between calcaneus and tibia on the **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 uses a slightly lower **41°** inclination angle, which may be slightly more accurate, but more significantly also used a **23°** angle (offset medially) in the transverse or horizontal plane to construct an analogue model (this later adjustment was not used by Verne **Inman** in the analogue modeling described in his classic, ***The Joints of the Ankle***. The Williams & Wilkins Company: Baltimore, 1976)

However, even without considering Rubin, the assumption 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°**, not **45°**. See "Kinematics of the ankle and foot". ***Acta Orthop Scand Suppl*** **60**: 1, 1989. (See also an excellent discussion of this assumption 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 et al. study was conducted on freshly amputated feet, dissected to bone and ligament alone. This difference may be important, since the dissected feet of Root were unloaded, whereas the living feet studies by Lundberg were presumably loaded by roughly ½ of the body weight of test subjects. A later study by E.J. **Van Langelaan** on loaded cadaver feet had results close to Rubin's joint axis angles, 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 last in Endnote[10], the latest and possibly best running decoupling study is by Katrina Mira **Fischer** et al. because it makes a strong case 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. That is to say, calcaneal adduction rather than calcaneal eversion, as shown in their **Figure 1** on **page 88**, is strongly coupled with tibial rotation.

Their barefoot running study yielded results of an observed average of **7.8°** of calcaneal adduction for an average of **12.1°** of internal tibial rotation - a **Fischer running coupling ratio** of calcaneal to tibial motion of **1:1.55**.

That Fischer running coupling ratio is nearly the same as the **Rubin static coupling ratio of 1:1.72** that was cited in Endnote[9] and illustrated in **FIGURE 5B.** Since Rubin's study measured foot supination and pronation, the similar results between the running and static ratios points to the conclusion that measuring calcaneal adduction tracks foot supination and pronation much more accurately than does calcaneal eversion.

This conclusion is further reinforced in the barefoot Fischer study, wherein the observed average of **4.7°** of calcaneal eversion for an average of **12.1°** of internal tibial rotation yields a ratio of **1:2.57**, a far higher ratio than the shod coupling studies cited above in Endnote[10].

All of the Ankle Joint Coupling Studies Have Serious Shortcomings

However, important factors unique to running have not been accounted for in any of these studies. For starters, the load on the foot and ankle joint in running is 4-6 times greater than a loaded cadaver foot with a simulated walking load of ½ body weight. And at room temperature cadaver feet are much colder and less flexible than living feet.

Both factors are going to significantly depress the longitudinal arch height of the living foot when running compared to tested cadaver feet, so that the subtalar joint axis is likely going to 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 (as shown in many published studies on the drop of the main longitudinal arch of the foot as evidenced by the lowered position of the navicular bone).

Furthermore, all the existing studies assume a vertical tibia, whereas at midstance in running the tibia is tilted forwarded about **20°** in dorsiflexion. In addition, the ankle joint itself is angled downward on the medial side in this maximally **20°** dorsiflexed ankle position. Neither of these important factors are included in the above ankle joint coupling studies cited in Endnote[9] or in Rubin.

As if these problems were not enough, there is another that is perhaps the worst of all. Although the average angle of inclination assumed in the Endnote[9] studies was **45°**, the actual range was from almost an angle of **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, average angles in inclination have to be derived for categories of runners, such as normal runners, pronating runners, and supinating runners. Obviously, the only truly accurate biomechanical approach is by each individual runner.

The huge **50°** range of inclination angles for the subtalar joint strongly suggests that each runner's angle is individually determined by the structural reaction to the effect of shoe heel-induced supination on his or her bones of the ankle joint complex.

Shoe Heels Have Greater Effect on Higher Arch Feet, Less on Lower Arch Feet

The bottom line relative to inclination angles of the subtalar joint in the sagittal plane is as follows. Individuals having supinated feet with higher longitudinal arches have inclination angles that are greater than **45°** have more tibial rotation for each degree of pronation or supination during running. Individuals having pronated feet with lower arches have inclination angles that are less than **45°** have less tibial rotation for each degree of pronation or supination. (This was 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 is an unusually critical point. It means that shoe heels will generally have a greater effect on individuals having supinated feet with high arches. For example, their tibias will be externally rotated farther during running, increasing the abnormal rotary structure of the modern knee shown in **Figure 9A**.

In contrast, shoe heels will typically have a lessor effect on individuals having pronated feet with low arches, and their tibia will be externally rotated less during running, so that their knees have a more natural, less non-rotary structure that is more like Figure 9B.

The change in the inclination angle 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 that is higher and rotated laterally, while lower arched individuals with pronated feet have a calcaneus 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 by conducting the simplest experiments possible to test the effects of gravity alone, so as to build a foundation for a general gravitational theory. Secondary factors like air friction are added in later to get results that match the real world.

Following this approach, 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 as a simple model of the gravitational force of attraction between planets.

In contrast, the existing basic biomechanics approach to the decoupling anomaly is as if the Galileo and Newton had tried to understand gravity by first studying the actual flight of cannon balls. If they had chosen to do so, gravity might still be a mystery today.

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

In contrast, without an accurate known baseline to measure against, all test results are just a confusing jumble of data noise, as has been the case heretofore in the study of human ankle joint decoupling.

So, so meaningful running research would logically involve human joint motion in the form of running, which is natural, as one principal difference from a baseline living stationary study. The other principal difference is shoes, which are artificial (and have increasingly major structural effects over time, a hugely complicating issue).

Both differences have to be evaluated with very careful empirical studies against the newly created known baseline, if a classical physics approach is to be followed in order to achieve success in obtaining meaningful results.

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

Besides his concern on ankle joint decoupling discussed above, Ned Frederick also noted in his comments on my book draft that there is not a standardized footwear measurement for the height of the shoe heel above the shoe forefoot, and no generally accepted measurement protocol.

It is certainly true that there is no consistency whatsoever relative to measurement of heel height in the industry (both last and footwear makers) or in the scientific studies of its footwear products, and that is a serious problem that needs resolution. Hopefully, my book will provide a powerful and long-needed impetus for real progress finally in that effort by the industry.

However, it remains unquestionably true today that it is an extremely simple matter to statically measure the essential structural difference in any footwear between the heel area and the forefoot area in a gross but highly meaningful way, even if less than perfectly consistent.

That is currently being done routinely, 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). Clearly, comparing heel heights can be hard and confusing, but still highly meaningful.

But Dr. Frederick also takes the surprising position that heel height must be dynamically measured during running at instants of maximum deformation in order for there to be any meaningful research results. To say the least, this would be difficult to do accurately, if not practically impossible today.

As noted first above, requiring this challenging approach seems like trying to discover the basic properties of gravity by first studying cannonballs in flight, instead of taking the far simpler initial approaches of Galileo and Newton of reducing a problem to its simplest principal factors measured in the easiest possible way. Static measures of heel height are without doubt good enough for meaningful biomechanical test results.

Moreover, it is unclear how dynamic measurement of heel height would be used. What is its purpose? Why do we need it? I frankly have no idea. What exactly is the potential benefit compared to static measurement? More practically, what is the cost versus benefit. Dr. Frederick is completely silent on all these critical issues and cites no references upon which his analysis might be based.

The closest and best comparison I can think of is this: although the side-to-side frontal plane deformation of footwear soles would seem to be at least equally relevant in the important study of running pronation and supination, no such equivalent capability currently exists to study dynamic lateral/medial compression of footwear soles.

Nonetheless, despite that absence, there are a very large volume of existing biomechanical studies that profess to provide meaningful results concerning pronation and supination. Unanswered is the question of why it has never been important to measure shoe soles dynamically in the frontal plane during running, but critically important now in the sagittal plane?

"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, 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 virtually any study, and never in rigorous detail.

Simply put, the structure of footwear soles is a critical but unknown and totally random variable in running biomechanics research, even in its simplest and easiest statically measured form. Does that mean that all such existing running biomechanics studies are sufficiently incomplete as to be generally incapable of producing reliable conclusions?

"Form follows function" is a truism in functional design, but the actual shoe sole form – this 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 spell out the actual structure of the shoe soles, which is the 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 sole ever typically measured in any way in these studies, even for basic size, much less 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 dynamic interaction during running. Perhaps some shoe companies do some small part of this, but all of their results are secret.

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

Finally, getting back to the outstanding Willwacher study discussed at the beginning of this endnote, one of its virtues is that its sample size is much larger than a typical biomechanics study, and includes both men and women. However, unfortunately it must also be pointed out that the runners studied are middle-aged, so on a de facto basis they are highly selected biomechanically, since they apparently have remained runners after surviving many years of annual injury rates as high as 70%.

Moreover, the study's runners were also limited to those runners who had been injury-free for at least the past 6 months, which makes them very unique indeed, again given the typical 70% annual injury rates.

Therefore, the test subjects were not at all randomly selected and do not at all reflect the overall population, even of their age group. Rather, they are highly filtered, elite winners who have triumphed in a lifelong "survival of the fittest" race in an age group in which nearly all other runners are former runners.

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

This is an extremely serious problem, since it means that there are no existing biomechanical studies on running that examine the effects of shoe heels on the general population. It is expected that in general such effects are far more adverse, with much greater abnormal distortion of joint motion and skeletal structure, than the relatively elite runners invariably used as test subjects.

On the positive side, the unique older runners in the Willwacher study above provide a rational guide to interpreting the study 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.

Given that Willwacher's data shows that the knee is being torqued into an unnatural varus position, it seems clear that the most effective compensation by runners successful in the long term is moderate pronation that offsets nearly exactly the abnormal torque caused by shoe heels. The same relatively straight-to-slightly-valgus legs is seen generally in world class champions.

However, a quick trip around any mall will convince you that this is not true for the overall population. A large portion of the males are significantly bowlegged when walking, whereas a similar portion of the females are significantly knock-kneed, as 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, ignoring the other leg on the generally accepted assumption that both legs are the same. However, that convenient assumption has now been definitively proven wrong, because the general case is, instead, that the right and left legs are in fact asymmetrical in form and function (see Endnote[13] directly below).

Of course, it is easy to understand why most studies have been limited to only one leg: it is extremely difficult to deal with all the data points needed from just one leg to adequately measure its function, let alone both legs, and then correlating the differences between them, while also correlating those leg differences with data points from other parts of the body. As wearable, wireless electronic technology evolves, that complexity problem will become much easier to solve, but historically it has been overwhelming. Not to mention the much higher cost.

An additional note: data from the Willwacher study (graph on **Knee Angles in Frontal Plane** – shown above) also provides clear evidence of the extraordinarily high 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 is also the most erratically variable of all the lower limb joint motions measured in the Willwacher study. This erratic variability is suggestive of wide individual variation in compensating for the excessive lateral instability in the modern knee joint due to the unnatural effect of shoe heels.

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.

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).

However, that is precisely the main problem with biomechanical studies on running in shoes: the animals are human Guinea Pigs, usually just a relative few and not selected randomly from the general population. The vast majority of the general population are non-active runners who are ignored by these studies, the results of which are therefore inherently suspect and potentially misleading.

12. **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.

Radzak, Kara N. et al. (2017). Asymmetry between lower limbs during rested and fatigued state running gait in healthy individuals. In ***Gait & Posture*** 51: 268-274, particularly **pages 270-272** and **Tables 2-3**. Irene **McClay** (Davis) in "The Evolution of the Study of the Mechanics of Running" in the ***Journal of the American Podiatric Medical Association*** **90**: 3: 133-148, especially **page 141** and **Figure 8**.

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

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 that

> **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).

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 less than 8 degrees has been reported to be 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 with 37 women in 2000, Makiko **Kouchi** and Emiko Tsutsumi also found that as the height of a shoe heel increases, the foot supinates, as did a study with 13 women in the same year by Darren **Stefanyshyn** and others.

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 study in 2002 by Timothy **Derrick**, Darrin Dereu, and Scott McLean indicated that 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*** *Medicine* 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 few examples of "barefoot" primitive knees listed in the text are the only photographic evidence publically available that I have been able to find. This is perhaps an appropriate point to state that none of the evidence that I have included in this article is intentionally "cherry-picked," although it might appear to be, since the evidence is limited and very spotty. But that is simply because it is all there is publically available, despite extensive effort to find more.

In fact, that shortage of useable evidence problem is the main reason why I am publishing my preliminary findings now, in much less than finished form, because a great deal of additional evidence certainly does exist all over the world in diverse locations, but is not publically available.

For example, a vast multitude of very old Caucasian tibia exist throughout Europe that could provide a good indication of the actual structure of primitive European "barefoot" Caucasian knees (although we can never know what kind of footwear if any may have been in common use where the bones were found, particularly in Northern climates.) More unequivocal evidence may be available from Caucasians who have grown up and live without footwear in South Pacific islands.

In the interests of the fullest disclosure possible, the only contrary publically available evidence I found was weak and is as follows: the tibia of an apparent family of British Neolithic humans (from around 10,000 A.D., about time agriculture developed) had an unusually elongated medial condyle. However, there is no indication of rotary motion like that in the modern European tibia shown in **FIGURE 9A** and there is 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.

16. Unpublished additional study data indicating about **14°** of inward tilt for 129 males has been generously provided by Dr. Willwacher[11] and 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°**.

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. **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.

19. **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.

Compare Foville's "barefoot" brain of **FIGURE 28B** with the well-known structure of the modern brain, as shown in **FIGURE 28E.** The torsional-shift anatomical asymmetries between the right and left hemispheres are shown in a bottom view, Figure 4.5 from page 126, of Gazzaniga, Michael S. et al. (2014). *Cognitive Neuroscience: The Biology of the Mind (4th Ed.)*. New York: W. W. Norton & Company.

20. **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.

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

22. **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.

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

24. Although this is just anecdotal testimony by the medical doctor, he is an unusually qualified individual, with a Ph.D. in Electrical Engineering, and a law degree as well, in addition to his medical degree.

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

26. 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.

27. 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.

28. Daniel L. **Lieberman** (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.

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