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UNNATURAL INSTABILITY:
Modern Shoe Soles Have a Major Stability Defect, Shockingly Dangerous and Costly, But Correctable

INTRODUCTION

In stark contrast to the COVID-19 pandemic, you will find it easy to follow the simple science and technology that is used here to describe the long-overlooked stability defect in common, ordinary shoe soles. You won't need to be an expert in anything. You can understand it all by yourself with minimal effort. Because it is so elementary, so fundamentally basic, it has been entirely overlooked, hidden in plain sight. On the other hand, once the simple defect is revealed, it instantly becomes obvious. But obvious only in hindsight.

Because of that utter simplicity, I believe that I can make what otherwise might sound like a preposterous promise. The promise is that, after reading this short book, you will be much better informed about the most important issue in the science and technology of modern footwear than the industry's own best experts. Furthermore, that promise is made despite the fact that the leading product of the footwear industry – athletic footwear – has had for many decades an unchallenged reputation for being a highly sophisticated product of the latest technology, the incredible complexity of most of which is usually incomprehensible to the non-expert.

I know that promise sounds unbelievable, but in reality, the promise will likely be fulfilled. The trick is that the most important technology of the footwear industry is not advanced at all, but instead is both quite simple and exceptionally old. So old, in fact, that old is not really the right word. Much more than very old, it is literally quite ancient. At least two thousand years old. Possibly much older, but at least so ancient that exactly how old is not known and probably not knowable.

That fundamental or core technology is the basic structural design of the soles of footwear. That design is crucial, since shoe soles are the de facto structural foundation of the modern human body, having in effect almost completely replaced the natural bare foot sole upon which the human body evolved for millions of years. The artificial shoe sole design is all the more critical when the human body is in motion, such as during running and active sports, when impact forces are very high and unfailing stability is indispensable to avoid serious injury.

Despite its critical importance, the artificial nature of the shoe sole with its drastically different structure and function, and the potential for those enormous differences to constitute serious flaws has never been carefully researched by the footwear industry. In fact, if funding is a reasonable measure, very little of anything has been carefully researched by the footwear industry. The little-known reality is that the most technically sophisticated part of the industry, the athletic shoe companies, even the largest, have historically spent relatively little on Research and Development (R&D).

There is not much public information available anymore, but, as last reported a few decades ago in ***Business Week***, footwear industry-leading Nike spent only 0.4% of its annual sales on R&D. That was only about a tenth as much on R&D as the average of all major U.S. industries then, which was 3.4% as percent of sales. In recent years Nike has not reported its R&D costs, such as in its 2020 Annual Report (or anywhere else that I could find), while Adidas apparently spent only 0.6% on R&D, as reported in its 2020 Annual Report.[1]

Moreover, virtually all R&D in the footwear industry goes into commercial product development. It does not go into research and certainly not into research sufficiently basic as to challenge the most fundamental assumptions about the structural design of soles. And in relative magnitude it does not compare to genuine high tech companies, where for example it was reported in 2020 that Amazon spent 11.1% of sales on R&D, Alphabet (formerly Google) 15.1%, Microsoft 13%, Apple 7%, Samsung 9%, and Meta (formerly Facebook) 21%.[2]

That enormous void in basic research in the footwear industry is critical, because it has allowed an ancient but major defect in sole structure to continue undetected in today's modern digital world. That is despite the footwear industry's abundant use of sophisticated technology by very well trained and intelligent personnel to do its R&D, design, manufacturing, and marketing.

Ironically, all that sophisticated high tech seems to have had the perverse effect of camouflaging the serious basic defect in shoe sole stability. The defect has been lost in the elaborate digital designs and exotic materials used in the soles of modern athletic shoes, as well as the very striking color schemes and other highly distracting visual details of the shoe upper, not to mention the endless cascade of ever-changing new footwear models and the intense focus on the superstar athletes that endorse them.

THE LONG-HIDDEN STRUCTURAL DEFECT

The modern conventional shoe sole is artificially unstable because its serious structural defect has always remained hidden. It has remained overlooked even today primarily because of a mistaken belief that the human ankle is inherently weak and unstable, since the ankle sprain injuries are the most common sports injury. The unchallenged consensus in the both the footwear industry and medical establishment is that the human ankle is obviously the problem.

Unfortunately, and inexplicably, until relatively recently no one bothered to simply look carefully at the stability of an ankle of a bare human foot that is not encumbered with a shoe sole. However, as you shall soon see, even the most casual observation of a bare foot at ground level makes it perfectly clear that the ankle joint is inherently quite stable in the absence of footwear.

The stark contrast with the inherent instability of the same foot in a shoe could hardly be greater. The stability difference between bare and shod foot is so extreme it could reasonably be characterized as the difference between night and day – in fact, a dark, moonless winter at midnight in contrast to a bright, sunlit summer day at noon. I believe that the simple evidence you will soon see here will make you agree that the actual difference is truly that glaring. In fact, you can even test and confirm the actual difference yourself, but only if you are very careful.

I believe that the direct result of this failure at the most fundamental level to perform even the simplest empirical test in basic science is a truly astonishing number of serious medical injuries, hospitalizations, and deaths that could have been avoided without great difficulty. Based on health statistics from the **U. S. Centers for Disease Control and Prevention** (**CDC**) on accidental falls,[3] if only **50%** of the reported falls are caused by the defective stability of conventional shoe soles – a very conservative estimate, given the evidence you shall soon see – then the defect resulted in about **20,000 deaths, 3,200,000 hospital emergency room visits, and 700,000 hospitalizations in the U.S alone in 2019** (the "normal", pre-pandemic most recent year for which data is available). **The resulting estimated annual cost of medical care is about $65 billion**, as well as $12.5 billion in the estimated annual cost of lost work. Those direct costs do not include an estimated $77 billion loss in value of statistical life and an estimated $533.5 billion loss of quality of life, again according to CDC data.

Of course, at this long overdue first step in the necessary basic research, the **50%** estimate can only be my best educated guess based on the available evidence. There is no firm basis for a more accurate estimate. However, even if only **10%** of the reported falls were caused by the shoe sole defect – which I believe is an impossibly low estimate, again given the compelling evidence that will soon be presented in this investigation – then the **highly probable result** is still only a more moderate avoidable medical catastrophe every year: **4,000 deaths, 646,000 ER visits, and 140,000 hospitalizations, with a medical cost of about $13 billion** and work loss cost of $2.5 billion. To these direct costs must also be added an estimated $15.4 billion loss in value of statistical life and an estimated $106.7 billion loss in quality of life. Again, just in the U.S.

If so, that would be roughly equivalent to a 9/11 magnitude event <u>every year</u>, although without any dramatic passenger jet crashes or massive building collapses. Instead, the damage to almost a million individual victims has been invisible, day by day slowly reaching virtually every city and town in the U.S. But unlike the single 9/11 event, this catastrophe is ongoing year after year.

Furthermore, the **worst-case estimate** is that the shoe sole defect, directly or indirectly, causes **most** of the **40,0000 deaths 6,460,000 ER visits, and 1,400,000 hospitalizations** that occur <u>each year</u> in the U.S. due to falls, at an **estimated medical cost of about $129 billi**on and an estimated cost of $25 billion in lost work, with an estimated loss of $153.7 billion in value of statistical life and an estimated loss of $1,067 billion in quality of life. Incredibly, I believe this worst-case estimate could well be closest in this range of three estimates to the actual cost of the shoe sole defect, based on a reasoned analysis that will be presented later in this investigation.

With that caveat, projecting that level of fall deaths for two decades would total about 800,000 total deaths or roughly 60% greater than the 500,000 total deaths due to the opioid crisis that has occurred in the U.S. during the last two decades. However, unlike the total of opioid crisis deaths, the very high level of fall deaths did not occur just for the last two decades, but also for previous decades. In fact, the unnatural level of fall injuries and deaths goes back centuries.

Putting these estimated U.S. annual medical costs in perspective, even the most reasonable middle 50% cost estimate of $65 billion is almost equal to the **estimated total world-wide annual footwear sales of about $82.5 billion of the branded athletic footwear industry**.[4] And that comparison ignores the estimated work loss of $12.5 billion or the estimated $77 billion loss in value of statistical life and the estimated $533.5 billion loss of quality of life caused by accidental falls. **Worse, total U.S. annual branded athletic footwear sales is only $31.2 billion**.

Despite the shocking magnitude of this potentially preventable catastrophe, judging from its current products, the footwear industry continues to be completely unaware of its shoe sole instability problem compared to the barefoot sole. Perhaps even more extraordinary is that with some simple guidance, it is easy for anyone to prove for themselves the existence of the inherent and artificial instability of conventional footwear, regardless of their expertise or lack thereof.

That includes you, the reader. As a matter of fact, in the following pages, I will show you how you can prove it without difficulty or special equipment in only a few minutes. All you will need is your own feet and a pair of conventional shoes.

But first, a little personal background before we proceed with that simple proof. After all, why should you pay any attention to my extraordinarily brash assertions about an ancient fundamental footwear sole defect? Who am I and what do I know about footwear anyway?

INVENTOR OF THE FIRST SHOE SOLES BASED ON THE SOLES OF BARE FEET

By way of introduction, I am a longtime runner, but a distinctly non-elite runner. To be more accurate now, I am, sadly, like the vast majority of longtime runners, now a former runner. At a relatively early stage in my running career, decades ago, I developed an assortment of injuries. Those recurring injuries forced me into what became an extensive investigation to find solutions to my own individual problems, going from treatment to treatment, continually searching for solutions that actually worked.

Initially, of course, I was just looking to solve my own persistent problems, and I became increasingly frustrated by my inability to find existing running shoes or orthotics or anything else that really worked to correct them. Eventually I put this ongoing frustration to constructive use. Beginning in 1988, I pioneered the first research and development on barefoot sole-based designs for shoe soles, particularly athletic shoes for running and basketball, my favorite sports.[5]

My investigation began when I more or less literally stumbled on the observation that the bare human foot, by itself, has far better lateral or side-to-side stability than when it is "assisted" by conventional shoe soles, as it invariably is in the modern world. My design goal then was therefore to invent new, more natural structures for shoe soles that retained that vastly superior lateral stability of the human foot sole when bare.

The barefoot sole designs I developed at that time preserve in a shoe sole the greater width, rounder shape and increased flexibility of the natural human foot sole. My immediate goal at that time was to prevent ankle sprains, a recurring problem of mine when playing basketball and one that is the most common sports injury (as well as the most common cause of hospital emergency room visits).

After about three years of hard work, in addition to a full-time job completely unrelated to footwear, I was awarded my first U. S. patent, and many more patents followed, including many foreign patents, for shoe sole structural inventions based on the barefoot sole.

A PATENT LICENSE WITH ADIDAS FOR BAREFOOT SHOE SOLE TECHNOLOGY

Three years later, in 1994, I succeeded in licensing that patented technology exclusively to Adidas. During the initial product development phase, Adidas dubbed the resulting footwear "**barefootwear.**" It almost immediately became Adidas' core shoe sole technology in all categories of new footwear (not including Adidas classics, which are old models that are still popular, like the ***Stan Smith*** tennis shoe). Adidas began marketing their footwear incorporating my shoe sole technology in 1996 as "***Feet You Wear***." **[FIGURE 1]**

To promote its new core technology, Adidas used its star athlete endorsers, including **Kobe Bryant** **[FIGURE 2]** shown wearing a very popular ***Feet Your Wear*** basketball shoe, the ***Crazy 8*** and an ad campaign that was its largest-ever at the time. **Steffi Graff** used the first ***Feet You Wear*** tennis shoe, the ***Integral***, to win the 1996 U.S. Tennis Open.

By 2001, Adidas had marketed about a hundred different models of **Feet You Wear** and similar shoes, including models in virtually every footwear category. But in 2003, the patent license was terminated following several years of litigation. A brief and generally accurate ***Sole Collector*** article summarizes Adidas' **Feet You Wear** program. **[FIGURE 3]**

Since then, besides developing several secure computer architecture inventions and some other non-footwear inventions, I have continued to invent improved footwear soles. I am currently the most prolific U.S. inventor of footwear sole technology by a wide margin, with over 50% more U.S. patents in the modern era (since 1970) than any other inventor, including those at the largest athletic footwear companies like Nike and Adidas.

Moreover, unlike corporate innovation teams that focus on developing incremental improvements to existing technologies, the focus of my inventions has mostly been on fundamentally new technologies to solve existing basic problems. My more than seventy-five footwear-related U.S. patents are listed on my website: **AnatomicResearch.com.**

In addition to the barefoot sole technology that Adidas developed into **Feet You Wear**, after extensive design and testing in 1989 and 1990 I also developed a sole technology using deep vertical slits or channels – typically referred to as sipes – in the bottom of shoe soles to provide barefoot sole-like flexibility in athletic shoes.[6] The basic elements of that siped-sole technology was used by Nike in its **Free** line of "barefoot" running shoes and other athletic footwear, and is widely copied elsewhere in the footwear industry. (There is more about the siped shoe sole technology in the **APPENDIX 2**, which provides some history with my personal take on several aspects of the embarrassingly primitive state of functional design in modern athletic footwear.)

Finally, several years ago I invented a new sole technology that I believe will be the future of footwear over the next few decades. It is **smartsoles** with sensors and configurable structures that are controlled by the wearer's smartphone, which can be connected to a cloud of computers. The cloud can use artificial intelligence (AI) and machine learning techniques applied to the big data received from, at first, hundreds, then thousands, and eventually many millions of smartsole wearers to optimize each individual's dynamic smartsole structure in real time based on the wearer's foot sole and biomechanical and anatomical data during walking, running, and sports.

I filed U. S. and international patent applications and received a U. S. Patent on this smartsole invention, Number US 9,030,**335**, on May 12, 2015. The title of the patent is "***Smartphone App-Controlled Configuration of Footwear Soles Using Sensors in the Smartphone and the Soles.***" It is also available to view on the Internet at my website: **www.AnatomicResearch.com** or at the **USPTO** website, together with many new and directly related issued patents, including in Europe. Others are pending.

Shortly after I was awarded the **'335** patent, an unsolicited but highly laudatory **YouTube** video appeared that described it in detail (mostly correctly), complete with animation and produced by a third-party unknown to me. It was a complete surprise. The **'335** patent had been singled out from many thousands of other new patents for special praise. You can see the video by searching **YouTube** for the title, "**Smart Shoe – finally humanity invents the shoe that it deserves**", or at the link: **www.youtube.com/watch?v=CjBhghWDMoM.**

THE SHOE SOLE'S BASIC DEFECT: HIGHLY UNSTABLE COMPARED TO BAREFOOT

Rear and underneath views of a **conventional shoe sole** illustrates emphatically the basic problem regarding its artificial instability. In the typical position of a lateral ankle sprain (the most common sports injury), the entire ankle joint and the body weight force transmitted through it are located outside of the tiny knife-edge of a shoe sole edge that contacts the ground support surface (which is a thick sheet of clear plexiglass). **[FIGURE 4 & VIDEO LINK]** Only the shoe wearer's ligaments and tendons around the tilted ankle joint provide structural support to it. The unavoidable result is serious ankle and leg instability, a particularly major problem given the unique bipedal structure of humans, who are forced to continually put all of their body weight, or many multiples of it, on a single foot and leg for support during walking or running.

In contrast, the tilted-out **barefoot** is stable, with opposing forces directly inline forming a stable equilibrium. **[FIGURE 5 & VIDEO LINK]** In the underneath view, the bare sole enjoys a wide base of support under the calcaneus (or heel bone) and the base and head of the 5th metatarsal bone (all three bones of the foot show up as the large white areas of the barefoot sole contacting the plexiglass). The contact area of support under the barefoot is over ten times the knife-edge area of support provided by the conventional shoe sole.

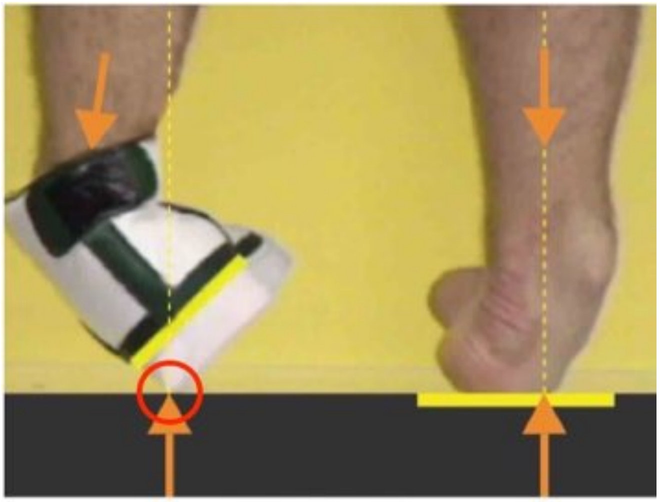


FIG. 4

FIG. 5

Although tiny, the knife-edge of contact (circled in **red** in FIGURE 4) between tilted conventional shoe sole and the ground concentrates enormous point pressure compared to the barefoot, almost digging in to firmly fix an axis of rotation for the unnatural outward twisting torque that forces the ankle joint over abnormally. The difference in point pressure is even greater when the knife-edge is compared to the conventional shoe sole when flat on the ground. The abrupt transition between the two vastly different traction states of conventional shoe soles is enormous and inherently destabilizing, and it is entirely artificial. The unnatural conventional knife-edge is in effect the **bleeding edge** of artificial instability.

As FIGURES 4 & 5 show, the stability difference between bare and shod feet in the lateral ankle spraining position is stark. It is a night and day difference. Polar opposites. The barefoot has naturally steady lateral stability. In direct comparison, the conventional shoe sole is abnormally unstable, an artificial defect.

The obvious question is, can the artificial instability of conventional footwear soles be corrected to make new footwear soles that are as stable as the bare sole? The answer is definitely yes. With limited resources, I have produced several different sole designs that demonstrate that barefoot-like stability, including factory made footwear samples. It is not rocket science.

TODAY THE LATERAL STABILITY OF ATHLETIC FOOTWEAR HAS BEEN GETTING WORSE

In recent years I have become increasingly troubled at the apparent absence of any progress in improving the stability of footwear, particularly athletic footwear. Actually, it is worse than that. I personally believe that performance athletic footwear now has distinctly less side-to-side stability than it had when I started working on the problem in 1988. Although the stability problem has gotten progressively worse, the basic answer to that problem is still the same as it was over thirty years ago.

To recap that now old solution, I developed a somewhat crude but highly functional **engineering prototype in 1993** of an athletic shoe that had a sole that was demonstrably, with no exaggeration whatsoever, lightyears ahead of any then-existing athletic shoe sole in terms of its far greater lateral stability. The basic secret to its breakthrough design could not be much simpler.

<u>STABLE SOLE DESIGN ELEMENTS:</u> The prototype sole was, in essence, structured like a <u>sock</u>, a thick plastic sock with (1) **uniform thickness** from side to side so it would not change the biomechanical performance of the bare foot inside. The prototype sole was (2) **rounded** like a human foot sole, (3) **flexible** like a human foot sole, and (4) **as wide as** a human foot sole. The rounded sides are located where there are (5) bone structures within the foot that required direct support.

With that simple sock-like sole design, the ***Anatomic Research Prototype*** **design was <u>biomechanically neutral</u>**, allowing the foot sole inside to react naturally with shoe sole as if directly on the ground. The shoe sole's proper functional role is limited to provide cushioning, insulation, protection, and traction to the bare foot – all necessary in the modern world of concrete, asphalt, and occasionally much worse.

My ***1993 Anatomic Research Prototype*****, FIGURES 6A-D** shown on the <u>left</u>, has an Adidas track racing shoe upper on my prototype shoe sole. **FIGURES 7A-D** shown on the <u>right</u> is a visually similar 1997 Adidas athletic shoe model, the ***Key Trainer***, a second generation ***Feet You Wear*** model.

FIG. 6A

FIG.7A

FIG.6B

FIG.7B

FIG.6C

FIG.7C

FIG.6D

FIG. 7D

As a practical matter, the design of my ***'93* Anatomic Research *Prototype*, FIGURES 6A-D** shown on the left, effectively eliminated ankle sprains, even in the most extreme conditions. In 1993, I successfully demonstrated that unique extreme stability in a test unlike any ever attempted before in the footwear industry. The test had never been tried previously for the simple reason that all conventional shoes then existing would fail the test, and all would almost certainly cause serious injury to the test subject wearing them (more about this test later).

That ***'93 AR Prototype*** shoe and my associated portfolio of U.S. and foreign patents covering its sole structure became the basis of an exclusive patent license with Adidas. Unfortunately, my license with Adidas was strictly limited to patents issues only. I had no role in developing footwear designs (other than having already provided Adidas with the ***'93 AR Prototype*** to evaluate at the beginning of licensing discussions).

I have no personal knowledge of what happened during footwear product design and development within Adidas during the license from 1994 to 2003, because I had no role in it. From public disclosures, I know that initially they seemed to see its extraordinary potential. At the major trade show introduction of Adidas' first commercial ***Feet You Wear*** models in 1996, Peter Moore, then the head of world-wide product development for Adidas and also the CEO of Adidas USA, said that …"in all my years in this industry, I have never seen footwear, technical or otherwise, that can do what these shoes can do. …It is about a concept and a technology that meaningfully helps athletes perform better and safer."[7]

As to what happened during the actual development of ***Feet You Wear*** by Adidas, I can only offer my personal opinion based exclusively on my own personal evaluation focusing on Adidas' commercial footwear products exclusively. Based on a simple lateral ankle sprain simulation test and a structural analysis of their soles, my personal opinion is that none of the first footwear products Adidas developed under our license had lateral stability equivalent to that of my ***'93 AR Prototype*** or of the bare foot itself. I think Adidas designers apparently recognized the lateral stability shortcoming in its first ***Feet You Wear*** footwear products marketed in 1996, and rapidly developed in 1997 a commercial version that looked very much like the ***'93 AR*** **Prototype** sample that I had given Adidas.

It was called the Adidas ***Key Trainer*****,** **FIGURES 7A-D** shown above, which was quite similar in sole structure and appearance (that is, as radically "unique" looking as my non-commercial engineering prototype[8], but which also had some sole structural changes that resulted in less lateral and medial stability). Based on my evaluation, the ***Key Trainer*** came the closest of all of Adidas' ***Feet You Wear*** shoes to the barefoot-like stability of the ***AR Prototype***.

A STRUCTURAL ANALYSIS OF THE CRITICAL DIFFERENCES BETWEEN MY *PROTOTYPE* AND THE ADIDAS *KEY TRAINER*

The most critical structural difference between my ***'93 Anatomic Research Prototype*** and the Adidas ***Key Trainer*** is a major difference in the accuracy of the necessary uniform thickness of the sole in the frontal plane. The uniform thickness of the ***AR Prototype*** sole that provides barefoot-like stability was highly accurate, as seen in frontal plane cross-sections taken at the heel in **FIGURE 6E**. Other ***AR Prototype*** sole frontal plane cross-sections taken at the midfoot (at the base of the 5^{th} metatarsal bone) and forefoot (at the heads of the five metatarsal bones) showed the same frontal thickness accuracy.[9]

In contrast, the thickness of the ***Key Trainer*** sole was not accurately uniform, again as seen in frontal plane cross-sections taken at the heel, in **FIGURE 7E**, although it is fairly close on the lateral (left) side.

Other ***Key Trainer*** sole frontal plane cross-sections taken at the midfoot (at the base of the 5^{th} metatarsal bone), forefoot (at the heads of the five metatarsal bones), and forefoot (at the phalanges or toes) are similarly inaccurate.[10]

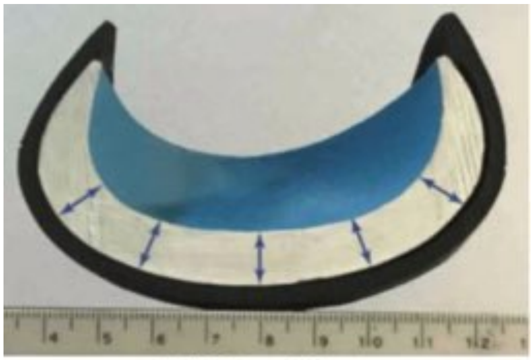


FIG. 6E

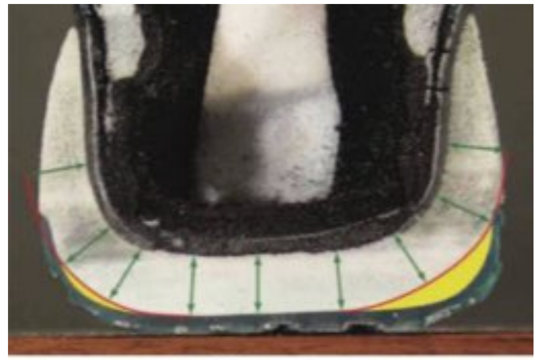


FIG. 7E

The red line indicates the uniform thickness in the frontal plane that is necessary for barefoot-like lateral stability. Note that only the thickness variation of the ***Key Trainer*** midsole (in white) is measured, since most of the shoe sole is sculpted out of the relatively thick cushioning midsole. In contrast, the outsole is typically thin with relatively uniform thickness, with most of its thickness variation due to a tread pattern that is uniformly thick in functional terms due to its consistency (although some modern outsole designs are more variable).

Excessive midsole sole side thickness (midsole that is outside the red line, shown highlighted in yellow) makes the sole function more like a conventional shoe sole that resists the natural lateral motion of the bare foot, but tilts and tips over in extreme sideways motion. Insufficient midsole side thickness (midsole that is not thick enough to reach the red line) allows the foot to, effectively, roll down-hill unnaturally and unstably.

In addition to this difference in uniform thickness accuracy, the ***AR Prototype*** and the ***Key Trainer*** also differed significantly in flexibility. The barefoot sole is highly flexible, its rounded portions easily flattening under a bodyweight load to conform to the typically flat ground. Compared to a conventional shoe sole, the ***AR Prototype*** was highly flexible, flattening under a bodyweight load like the barefoot.

However, the ***Key Trainer*** sole was relatively rigid like a conventional shoe sole. As a result, when it was forced into a tilted position so that its rounded side contacted the ground under a bodyweight load, the shoe sole did not flatten. Although it was not supported by only a thin knife edge like a conventional shoe **[FIGURES 4 and 5]**, the relatively rigid rounded side of the ***Key Trainer*** sole was subject to a "rocking chair" effect that made it significantly less stable than the ***AR Prototype***.

The ***Key Trainer's*** conventional sole rigidity also exaggerated another stability problem in the critical heel area, compared to the barefoot and the ***AR Prototype***. They both have a fully rounded heel that deforms to flatten under a bodyweight load. The fully rounded heel has a relatively large radius of curvature, so that the deformation is gradual and continuous over a large area of the heel).

However, the ***Key Trainer*** sole has a central flattened section like a conventional shoe sole. That central flattened section forced all of the rounding of the sole to the sides (technically, with a much smaller radius of curvature). As a consequence, more of the deformation is focused on a smaller area more abruptly. The relative rigidity of the ***Key Trainer*** sole made that deformation in the heel area much more difficult, so that it could not tilt as stably as a barefoot.

In hindsight, it seems likely to me now that Adidas was forced to use a flattened heel design in part because of a fundamental manufacturing limitation dictated by a conventional footwear industry technology that existed then and now.

Like other footwear companies, Adidas uses **shoe lasts** for the critical assembly operation of positioning and attaching the shoe upper to the shoe sole. Unfortunately, all conventional shoe lasts have a flat heel bottom, so Adidas was forced to incorporate a flat central portion in the heel sole for ***Feet You Wear*** shoes to mate to the flat heel last, with the sole curvature located only on the sides of the flat portion, thereby forming sharply curved sides (see **FIGURE 7F**).

Unfortunately, because Adidas kept the flat middle section of the shoe sole, it was not necessary to develop increased flexibility into the shoe sole to allow it to flatten under a bodyweight load the same way the human foot does. That is, the ***Feet You Wear*** shoes were already deformed in just the right way to support conventionally the standing, upright foot. In the typical lateral ankle spraining position, the result was a relatively rigid, tilted conventional sole in ***Feet You Wear*** shoes. The sharply curved sides added the sideways rocking chair effect.

In contrast, my ***'93 AR Prototype*** is curved gradually and continually throughout the bottom and sides of the shoe sole, so that it parallels far more precisely the shape and structure of the unloaded bare foot sole, particularly the unloaded heel (see **FIGURE 6F**). The sole of my ***'93 AR Prototype*** was much better adapted structurally to enable barefoot sole-like lateral stability because it was sufficiently flexible to parallel the foot sole flattening under a bodyweight load.

That flattening is especially important when the shoe is fully tilted in supination into the typical lateral ankle sprain position. That degree of shoe sole flexibility is absolutely critical in order for the shoe sole to provide the same superior stability as the sole of the bare foot.

Like other athletic footwear companies, it seems likely that Adidas had an enormous investment in its available inventory of athletic shoe lasts developed over many years for many different types of shoes (one for each shoe size, both left and right feet), but presumably had no curved bottom lasts to copy the fully curved sole structure of my ***'93 AR Prototype***. Therefore, presumably none would likely have been available without a major time delay and considerable added expense.

So I am guessing that Adidas simply went with what they could manufacture without significant time delays or added expense. At the time, Adidas indicated publicly that it was encountering other construction difficulties in the first new ***Feet You Wear*** commercial models that were temporarily delaying expansion of its production during the initial phase.

Personally, I do not remember even considering Adidas' flat last problem at the time, because I had a very simple approach to create a rudimentary curved-bottom last for the ***AR Prototype*** that did the trick. More about that later. Obviously, however, I only had to make a few prototypes, while Adidas had to have a viable way to manufacture many millions of shoes.

For the future, this brief structural analysis highlights a critical design issue. If a shoe last with a flat heel bottom is used, then the shoe sole must have greater than conventional flexibility in order for the sharply curved side to flatten so as to have barefoot-like stability. Otherwise, it will not tilt as stably as a barefoot.

Likely due to its rather "unique" look, the ***Key Trainer*** was apparently not a commercial success. Although I did not have access to sales figures, I was able to purchase a number of ***Key Trainer*** pairs at steep discount. After the ***Key Trainer***, for reasons not known to me at the time, no other models Adidas produced later seemed to me to come as close in terms of lateral stability performance to my ***'93 AR Prototype*** with its exceptional capability to prevent ankle sprains.

Although, again, I do not have supporting sales data, I believe the most popular ***Feet You Wear*** model was the ***Crazy 8*** basketball shoe, famously worn by Kobe Bryant early in his NBA career [see **FIGURES 2 & 3**]. Unfortunately, under the same structural analysis of cross-sections in the frontal plane as the ***Key Trainer***, it is clear that the ***Crazy 8*** has considerably less accurate uniform thickness on the lateral (left) side in than the ***Key Trainer*** in the heel cross-section shown in **FIGURE 7G**.

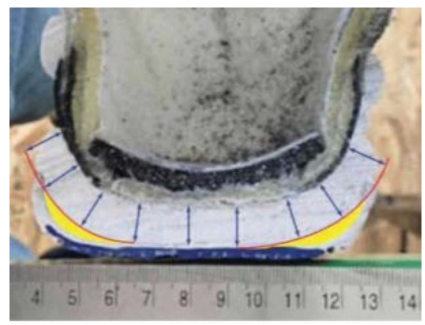


FIG. 7G

Other ***Crazy 8*** sole frontal plane cross-sections taken at the midfoot (at the base of the 5th metatarsal bone), forefoot (at the heads of the five metatarsal bones), and forefoot (at the phalanges or toes) are similarly inaccurate.[11]

Other ***Feet You Wear*** basketball shoe models worn by Kobe were similarly structured in terms of uniform thickness accuracy, as were some other ***FYW*** shoe models in other categories, based on the same kind of structural analysis of frontal plane cross-sections. Although these Crazy 8-like shoe models did not have barefoot-like stability, they were at least measurably more stable than other basketball shoes of the era, according to a contemporaneous research study.[12] Unfortunately, that stability standard was a pretty low hurdle to clear.

It is also clear from the same kind of structural analysis of frontal plane cross-sections performed on the many other models designed by Adidas that many other ***Feet You Wear*** shoe models had less uniform thickness accuracy. So, based on the preceding structural analysis of the ***Key Trainer*** and the ***Crazy 8***, as well as many other ***Feet You Wear*** and other Adidas models (over a hundred Adidas shoe models were dissected so that they could be cross-sectioned to allow for frontal plane evaluation), I personally think it is reasonable to conclude that, for whatever reasons, Adidas did not fully develop the true natural stability potential of my barefoot-based shoe sole technology.

It should be noted, of course, that digital footwear design and mass manufacturing twenty-five years ago was very primitive compared to today's technology, so Adidas' pioneering efforts then at building barefoot sole-shaped shoe soles was far more difficult than it would be to do so today. As a matter of fact, back then I was forced after an embarrassing failure to abandon an attempt to design my ***'93 AR Prototype*** using digital methods because the available hardware simply could not cope with the large number of pixels needed to describe the complex shape of the human foot. My ***'93 AR Prototype*** was actually designed and built strictly through analogue means, including the expert work of a toy prototype maker, who built the casting mold for the ***AR Prototype*** sole using thin layers of wax shaped by hand.[13]

I BELIEVE I HAVE A DUTY TO ACT NOW, BECAUSE NONE OF THE SHOE COMPANIES HAVE FIXED THE SOLE'S BASIC STABILITY DEFECT

As far as I can tell, in the past two decades neither Adidas, Nike, nor any other athletic or other footwear company has developed my technology to prevent ankle sprains or falls (or any other effective extreme stability technology, since none to my knowledge currently exists). My basic U.S. utility patents on the barefoot sole technology expired in 2011, so any company could have done so legally after that date. But none has in the more than a decade since 2011. Instead, many current performance footwear products have regressed into greater lateral instability.

So, after all these years, I felt I had a personal obligation to do something, since no one else has, in reaction to the ever-worsening lateral stability problem. Based on firsthand knowledge, I know with absolute certainty that it is possible for commercially manufactured shoe soles to be far more stable that they have ever before been. Making them so requires some significant modifications to the basic conventional structural design that is in current use, but those modifications are not all that difficult either to design or manufacture, especially with the modern digital systems and materials now available. I know, because I have done it multiple times over a period of many decades, each time with different design and construction techniques. Therefore, I believe that there is simply no doubt today's modern footwear industry can just also do it with little difficulty with their vastly greater resources.

As you will see from my discussion about footwear stability technology that follows, my various stable footwear designs evolved continuously after beginning in 1988. I am including here many contemporaneous photos, videos, and other original illustrations from my work as it developed over past decades.

THE BASIC LATERAL STABILITY PROBLEM OF CONVENTIONAL SHOE SOLES

The most basic part of the instability problem is that soles of modern shoes are structurally nothing like the soles of your feet. In a fundamental concept that has never been seriously questioned, shoe soles are basically designed like portable cookie-cutter sections of the flat ground that are attached to the shoe uppers, which are the only part of the conventional shoe that is curved to the rounded shape of your feet.

These flat conventional shoe soles are also relatively narrow and rigid. In contrast, the natural loadbearing portion of the soles of your feet are much rounder, much wider, and much more flexible (becoming rigid only under the pressure of body weight loads).

As you might guess, this fundamental structural design mismatch between the soles of modern shoes and the soles of feet causes major performance and stability problems for footwear that are entirely unnatural. Put bluntly, the stability of modern athletic shoe soles is embarrassingly bad compared to the soles of bare foot.

SUPERSTAR ENDORSERS ARE THE BASIC BUSINESS MODEL FOR SUCCESSFULLY MARKETING ATHLETIC SHOES

Going back at least as far the Chuck Taylor All Star basketball shoes of the 1930's, athletic shoes have been marketed to aspiring athletic consumers, especially the young ones, as the same shoes that superstar athletes wear.

In modern times, the most classic example of this business model is the famous 1980's Nike TV ad starring Michael Jordan and Spike Lee titled, "***It's Gotta be the Shoes***." In it, Spike keeps insisting the Michael Jordan's otherworldly athleticism is due to his shoes, while Michael denies it. Another ad shows Air Jordan basketball shoes providing rocket assistance, which presumably enables Michael's otherworldly jumping ability. The dialog is all tongue-in-cheek, but all the more effective because of the hip nature of it all. Spike Lee is still starring in "***Its Gotta be the Shoes***" television ads in 2021.

Besides naming shoe models for specific superstar endorsers, another industry advertising example is the marking of shoes to emphasize their direct connection to elite athletes, like this ***Nike Free*** running shoe claim to be "*…engineered to the exact specifications of world-class runners est. 1972.*"

Also included on the sole is a logo of the legendary **Bill Bowerman**, co-founder of Nike and inventor of its famous ***Cortez*** and ***Waffle Trainer*** running shoes (the latter with sole prototyped using a kitchen waffle iron) and coach of the 1972 U.S. Olympic track team In addition, he was co-author of the book, ***Jogging*** (1967), which sold a million copies and is said to have played a major role in igniting the running revolution of the 1970's (see **FIGURE 7H**)[14]

It follows from their advertising focus on superstars that the athletic shoe companies would, obviously, provide those superstar endorsers with the very best shoes that their most sophisticated footwear technology allows. It therefore reasonable to expect that the top-of-the-line high tech shoes of the superstar endorsers would provide the best possible stability in order to avoid costly injuries.

NBA SUPERSTARS GET THE VERY BEST OF MODERN SHOE TECHNOLOGY, BUT STILL HAVE MAJOR SHOE SOLE STABILITY PROBLEMS THAT CAUSE SERIOUS INJURIES

Even casual attention to professional sports events on broadcast or cable television strongly suggests that the shoes of superstar athletes have demonstrably poor lateral stability. Just using the slow-motion feature on a DVR to reduce the speed of the action and stopping it to blow up freeze-frame stills produces uncomplicated results that are dramatically compelling in the way that only visual data can be.

Although the video quality is often less than optimal, the results still clearly indicate an amazing lack of footwear stability in the performance shoes of the most elite superstars. Despite the fact that this basic video analysis is simpler than the average high school science experiment, the visual facts it produces, while raw, are solid evidence of shoe instability that is common even among NBA superstars.

For example, see **FIGURE 8** **[& VIDEO LINK]**, which shows the shod foot and ankle of NBA MVP **Kevin Durant** during a sharp cut he made quickly changing direction during a training session in 2014. At the time, he was recovering from a **Jones fracture of his right foot**.

Durant became the league's MVP at the end of the NBA season in June of 2014. His foot fracture was diagnosed before the start of the next season in October. Durant ended up missing almost that entire season due to an assortment of associated recurring injuries.

It is important to understand that a Jones fracture is a common break of the fifth metatarsal bone, the break occurring close to the relatively wide base of the 5th metatarsal. The 5th metatarsal base is located in the middle of the human foot on the outside or lateral edge.

The 5th metatarsal base just happens to be the precise part of Durant's foot that has rolled farthest off the performance basketball shoe sole he is wearing in **FIGURE 8**. As shown, his 5th metatarsal base has no direct physical support whatsoever, since the shoe sole is actually much narrower there, with a pronounced indentation at the lateral midfoot, an almost universal practice in athletic shoe sole design.

It does not take a Sherlock Holmes to conclude that the obvious mismatch between his foot sole and a typical shoe sole like that shown above could have played a major role in Durant's Jones fracture of his foot. The mismatch also likely caused his prolonged difficulty in getting the fracture to heal properly when he continued playing pro basketball at his unique superstar level.

The most extraordinary aspect of **FIGURE 8** is that it shows a "normal" sharp cut or pivot. It is not part of an injury sequence, even though a large part of the superstar's foot is not structurally supported by any part of the shoe sole, but instead has rolled off the outside edge of the shoe sole and consequently is literally hanging by the threads of the fabric of the shoe's upper, which also includes a midfoot strap.

Unfortunately for Kevin Durant, the fundamental mismatch between his 5th metatarsal base and his conventionally designed basketball shoe sole continued (despite the fact that he gets his own specially-designed new shoe version each year). This time the mismatch apparently causing a season-ending **Achilles tendon rupture on his same right foot** during a critical game five of the 2019 NBA championship finals.

Despite the imperfect quality of the broadcast video taken at the split second after the tendon rupture, it is still evident in both front and rear views **[FIGURES 9A and 9B & VIDEO LINKS]** that Durant's foot is in essentially the same position relative to his shoe as it was in FIGURE 8, with his right foot again rolling off the outside edge of his shoe sole as he attempted to push off while cutting to his left, again leaving his 5th metatarsal base hanging in midair, without direct structural support.

Although only my hypothesis, from what we can see it is logical biomechanically to conclude that Kevin's outward rolling foot – which would automatically invert his calcaneus or heel bone, tilting it to the outside – would thereby also automatically put unnaturally excessive tension on the most lateral or outside portion of his Achilles tendon attachment to the inverted calcaneus.

That recurring excessive high tension over time would likely cause the tendon to split first at that specific location due to the constant unnatural fatigue. Once the split started, the continuing excessive oblique tension would cause it to rip across the tendon, rupturing it entirely. There is currently no other reasonable explanation of his rupture's cause (nor, for that matter, any general explanation of the many other athlete's ruptures of the Achilles tendon).

In addition, it seems likely that Durant's Achilles tendon may also have been weakened over time by the cumulative effect of repeatedly twisting his ankles to the outside even when that did not result in severe injury, as shown in a typical example in **FIGURE 10A & VIDEO LINK**.

A view of his shoe while making a normal, non-injury producing cut in his 2021 signature basketball shoes, the **KD14**, as shown in **FIGURE 10B & VIDEO LINK.** It shows little if any stability improvement from **FIGURE 8** in 2014.

Durant's Achilles tendon rupture is not a unique problem. Kobe Bryant ruptured his Achilles tendon in 2013, effectively ending his last attempt at an NBA championship, and likely due to the same footwear sole stability problem. What is known with certainty is that the lateral instability problem of existing footwear indicated above is by no means limited to Kevin Durant. All conventional performance athletic footwear, even that worn by other NBA superstars, have the same basic instability problem, as demonstrated by this sequence showing two prior NBA Final MVP's during the 2019 NBA Final, a cutting Kawhi Leonard (middle photo) and Andre Iguodala attempting to guard him (but being forced to "break his ankle" in basketball street-talk).

Finally, to remove any possible remaining doubt, the right foot of Ty Jerome of UVA is shown in a cutting sequence the NCAA 2019 Semi-final game (during the infamous last second double-dribble play). As noted before, in these "normal" cutting motions there were <u>no ankle injuries</u> that interrupted game play, despite the extreme instability demonstrated. That degree of instability is just "normal". **[FIGURES 11A-11B & 12 & VIDEO LINKS]**

THE SAME LATERAL INSTABILITY OF CONVENTIONAL SHOE SOLES CAUSES ANTERIOR CRUCIATE LIGAMENT (ACL) TEARS

Jamal Murray is a budding NBA superstar whose breakout season was ended suddenly in a game just prior to the 2021 NBA playoffs by an anterior cruciate ligament (ACL) tear in his left knee. A video sequence of his season-ending injury shows Jamal's foot rolling to the outside, forcing his foot to roll off the lateral edge of the sole of his high-tech basketball shoe, automatically tilting the shoe sole laterally onto its outside edge. **[FIGURE 13A & VIDEO LINK]**

With his foot on the ground in that locked supination position and his shoe firmly planted by the ground reaction force, his lower leg became a lever arm that pivoted around his ankle joint. As a result, the full bodyweight force on his left thigh that automatically pushed his knee downward also automatically pushed it unnaturally inward. The inward force component of his total bodyweight force (at least 3 G's) increased steadily as his lower leg rotated inward when his knee was forced downward, creating a progressively increasing torque that pushed his knee farther and farther out of a normal straight alignment with his thigh.

As Jamal's lower leg was bent to the outside far out of alignment in the frontal plane, it created enormous unnatural tension in his knee joint ligaments. At the same time, his foot was locked into a maximal supination position, which rotated his tibia to the outside as far as it can go, while his femur was powerfully rotated maximally to the inside in the opposite direction in the horizontal plane. The unnatural and powerful torques on the tibia and femur bones in both frontal and horizontal planes occurring simultaneously must have caused the tear to Jamal's anterior cruciate ligament, apparently the weakest link of his knee ligaments.

This analysis is only a hypothesis, but again, like Achilles tendon tears, there is no other explanation for ACL tears, other than the hopeless resignation that it just happens from human weakness. Although the available broadcast video is of poor quality, it is still abundantly clear that Jamal's ACL tear occurred in conjunction with his foot being rolled to the outside into a fully supinated position, off the lateral edge of his shoe sole, just like Kevin Durant's foot when he tore his Achilles tendon. The only difference is the injury location in the knee instead of ankle.

Projected at the time to go sixth in the NFL draft, **Jameson Williams** was the superstar wide receiver of the Alabama University football team, which was favored to win the 2022 NCAA National Championship game against the University of Georgia. However, after catching a long pass from Heisman Trophy winning quarterback Bryce Young for a 40 yard gain early in a tie game, Jameson tore the ACL of his left knee. Without him for the rest of the game, Alabama lost.

As seen in this front and rear video sequence, Jameson's left leg was in straight alignment as his football cleat made ground contract. As his highly unstable cleat became firmly planted on the ground by his bodyweight, it rolled noticeably to the outside, unnaturally moving his lower leg inward out of alignment with his thigh.[14A] In the last frame, as his foot is in the push-off phase of ground contact, his ACL has been torn, with the medial plateau of his tibia creating a grossly abnormal knee bulge that is visible in the frame. **[FIGURE 13B & VIDEO LINK]**

Similarly, **Kawhi Leonard** tore the ACL in his right knee during the 2021 semi-final of the NBA's Western Conference in the same position, with his right foot rolled to the outside, off the lateral edge of his shoe sole, when his injury occurred, as seen in **FIGURE 13C & VIDEO LINK**. His injury was initially characterized as a sprained knee, but was later classified as an ACL injury and he underwent surgery. He was not able to return to the 2021 playoffs.

As seen in **FIGURE 13D & VIDEO LINK**, this same unstable position occurred during a routine cut a few weeks earlier that did not result in injury to Kawhi, so his ACL injury appears to have occurred as a result of repetitive abnormal stress, although he was also pushed to the outside by an opposing player when the injury occurred, so the additional load may also have initiated the tear.

Similarly, tennis superstar **Serena Williams** was forced to withdraw from the 2021 Wimbledon tournament in the first round by a simple slip on Centre Court. Her left leg slipped backwards, causing her right foot to roll to the outside, off the lateral edge of her shoe, resulting in an injury to her right knee, as seen in **FIGURES 13E&F & VIDEO LINK**.

Collegiate superstar **Paige Bueckers** fractured her anterior tibial plateau and tore her lateral meniscus of the left knee when her left foot slipped forward after she planted it to make a cut around a defender (frames 1 & 2), as seen in **FIGURES 13G-H & VIDEO LINK**. That slip caused her left knee to lock into a valgus position under a full bodyweight load (frames 3 & 4). The extreme lateral force on her left foot caused her left foot and shoe to tilt outward (frame 5).

As with the knee injuries to Durant, Murray, Leonard, and Williams, her knee damage occurred when her shoe supporting it was tilted unstably to the outside while under heavy bodyweight load.

The injury is particularly notable because Paige is the best player in women's NCAA basketball, having become the first freshman to win the Wooden Award and Naismith Trophy, while also being named the Associated Press Player of the Year. Although her injury occurred early in the 2021-22 season, she was not be able to play for two months. During the summer preseason, she torn the ACL of the same knee, so she will miss the 2022-23 season.

After Kevin Durant ruptured his Achilles tendon in game 5 of the 2019 NBA Championship Finals, the third superstar of the Golden State Warriors, **Klay Thompson**, tore his anterior cruciate ligament (ACL) in game 6 and the Warriors lost the championship to the Toronto Raptors.

As shown in **FIGURE 13I & VIDEO LINK**, Klay's injury is an important example because it indicates clearly that an ACL tear can occur in a single stage when the wearer's foot is just in an extreme pronation position – that is, rolling off the inside or medial edge of his basketball shoe – without first being in an extreme supination position demonstrated in the previous example FIGURES 13A-13H. Extreme force on the medial edge of the shoe sole locks down an axis of rotation on the sole's knife-edge, forcing the lower leg to rotate around it.

In game 1 of the 2021 NBA Finals, Dario Saric of the Phoenix Suns tore his anterior cruciate ligament (ACL) of his right knee and the Milwaukee Bucks went on to win the NBA championship. His injury was recorded in the best broadcast video of any of the examples I have found, as seen in **FIGURE 13J & VIDEO LINK**. I think the VIDEO LINK quality is good enough that you can actually see the distinct change in his knee as the ACL lets go. As a matter of fact, the short, slow motion VIDEO LINKS for all of the figures show the injury mechanisms much better than the limited frame sequences necessarily that were used here.

His injury is also an important example because it indicates a torn ACL that occurred without rolling off the outside or lateral edge of his conventional shoe sole, probably because his leg was at too extreme an angle from vertical when his left foot landed. Nevertheless, it is clear in the higher quality video that the ACL tear occurred when his inverted right foot and shoe rolled out laterally until it was approximately flat on the ground (indicated by the shoe sole and its reflected floor image almost touching in frame 4) and fully supinated.

SOME TENTATIVE SIMPLE CONCLUSIONS ABOUT THE CAUSE OF COMMON KNEE INJURIES BASED ON THESE EXAMPLES

All of the preceding examples demonstrate that knee injuries like torn ACL's and fractured tibia bones occur at the same time that conventional shoe soles are moving into or out of a significantly tilted position, involving either extreme foot supination or pronation, both positions being highly unstable. The lack of natural stability between conventional shoe soles and the ground appears to be transmitted up to the knee, creating in that joint unnatural instability and excessive torsion in both frontal and horizontal planes. The resulting repetitive excessive load or extreme overload causes knee damage such as a torn ACL or a broken tibial plateau.

It also appears that in all of the preceding sequence examples (and also including FIGURE 43) the foot and subtalar joint are locked in a maximally supinated or maximally pronated position, so that little or no natural horizontal or frontal plane motion can occur in the locked foot or ankle joint. The consequence of that severe artificial immobility of both foot and ankle joints would have to be that the knee joint directly above it is forced to cope with an excessive degree of unnatural joint motion to compensate for the loss. That excessive joint motion can exceed the normal design limits of the human knee, leading to acute knee ligament failure due to massive overload or repetitive overuse.

THE BASIC STRUCTURAL DESIGN OF CONVENTIONAL SHOE SOLES IS AT LEAST 2,000 YEARS OLD

The obviously pathetic functional performance of even the most modern conventional shoe soles might seem less surprising if you understood that the fundamental structural design of those soles, including the high-tech performance athletic shoes like those shown above, is extraordinarily old, developed originally by ancient shoe cobblers. Its origins go back at least two thousand years to the standard military sandal, the caliga, of the Roman Empire, which was the athletic shoe of its day **[FIGURE 14A]**, and a similar example of ancient sandals **[FIGURE 14B]**.

The same structural outline used by ancient cobblers is still used in nearly all modern shoe sole designs. **The outer edge of the shoe sole roughly matches the outer edge of the footprint of the wearer who is standing immobile and upright.**

The outer edge of the shoe sole was formed by cobblers simply by tracing the outer edge of foot sole where the sole contacts a layer of shoe sole material while the future shoe wearer was standing still and upright on the sole material, usually leather. Most custom shoe-making cobblers still use this simple tracing procedure to create an outline of the future wearer's foot sole.

Modern shoe soles are made with the latest high-tech cushioning and traction materials using the most modern digital computer-based design and manufacturing technologies. They appear to be using all of the highest available technology, as they are. But that may be in effect modern window dressing, since the most basic structural design of modern soles is nevertheless quite ancient and essentially unchanged today in any important way from the ancient Roman military sandal.

Of course, very old or ancient is not necessarily bad. The most basic structural design of the ancient wheel and the modern wheel is essentially the same, simply based on a geometric circle. The problem is that conventional shoe soles have structural problems that human foot soles do not because they do not share the same simple design.

THE STANDING ANKLE SPRAIN SIMULATION TEST

The most direct result of the unnatural structural instability problem of shoe soles is ankle sprains, which are by far the most common sports injury. Ankle sprains are also the most common cause of visits to hospital emergency rooms, even though the majority of ankle sprains are never treated in a hospital nor seen by any medical professional. In addition, the artificial instability problem obviously also causes ankle breaks, as well as accidental falls, either independent of ankle sprains and breaks or caused by them.

It is easy to prove that the modern human ankle joint is nearly impossible to sprain when the foot is removed from modern footwear and examined when bare.[15] You can prove this exceptional natural barefoot stability for yourself quite easily.

STANDING ANKLE SPRAIN SIMULATION TEST

Step 1: Barefoot To begin, take off one of your shoes. While standing upright and keeping most of your body weight on your other foot, carefully roll the **barefoot** to the outside. That is the position in which most ankle sprains occur.

Nevertheless, your barefoot and ankle will feel naturally stable, the rounded portions of your foot flattening to provide a wide base of support, particularly in the heel area. **[FIGURE 15]**

FIG. 15

Step 2: In-Shoe In contrast, if you roll your foot to the outside in a shoe with a conventional sole, the shoe sole automatically tilts outward, thereby making your foot **highly unstable**. If you roll your foot far enough, the angle of tilt of your shoe sole will inexorably reach a **tipping point**, balanced on a thin knife edge, restrained only by the ligaments and tendons of your ankle. Tilting beyond that tipping point risks causing your shoe-equipped foot to roll over, out of control. **[FIGURE 16]**

FIG. 16

FIGURE 16 shows a shod left foot at a tipping point, but in a controlled state, the wearer standing motionless with only half a bodyweight on left foot. Most decent athletes without prior ankle sprain problems can maintain control with their muscles and ligaments at this lightly-loaded tipping point. However, be forewarned that this controlled stability is quite misleading.

If you have much weight on that foot in this lateral ankle spraining position, such as when you are walking, running or jumping (with at least one to three to seven times bodyweight on that foot), the tilted shoe sole will likely cause your ankle to be sprained or fractured, especially if you have weakened ankles from past ankle sprains, as is often the case. Even the most robust superstar athletes manage prove this point all the time (see **FIGURES 35-37**).

The resulting immediate and intense ankle pain also automatically causes you to fall, in order to avoid putting any weight on the intensely painful ankle. The uncontrolled fall puts your foot, knee, hip, head, and other body parts at risk of serious injury too.

DO NOT EVER TRY THIS STABILITY TEST **(FIGURES 15 & 16)** BY YOURSELF. EVEN IF YOU ARE FIT. YOU CAN EASILY FALL AND HURT YOURSELF BADLY! BUT ESPECIALLY DO NOT TRY THIS IF YOU HAVE ANKLE PROBLEMS OR ARE DISABLED OR FRAIL OR OTHERWISE STABILITY-IMPAIRED IN ANY WAY!

ALSO, TO STAY SAFE IF YOU TRY THIS TEST, YOU MUST HAVE A SAFETY SPOTTER WHO IS STRONG AND AGILE ENOUGH TO SUPPORT YOUR BODYWEIGHT

FOR YOU, IN CASE YOU BEGIN TO SPRAIN YOUR ANKLE AND START TO FALL! USE YOUR HAND ON THE SAME SIDE AS THE SHOE YOU ARE TESTING TO HOLD THE SAFETY SPOTTER'S HAND TIGHTLY, AS SHOWN IN **FIGURE 17**!

Otherwise, to avoid any risk, try this first. Just put the shoe you previously took off onto a table top and tilt it to the outside. If you lower your head to the level of the table top, you can easily see for yourself how the tilted conventional shoe sole teeter-totters unstably on a relatively rigid knife edge of support, like **FIGURE 16**, completely unlike the flexible sole of your bare foot, which flattens under pressure into broad base of support.

FIG. 17

The difference in stability between barefoot and shod conditions is so drastic that it is obvious to anyone, even a six-year-old, as shown, who can experience for themselves the **Standing Ankle Sprain Simulation Test** on any conventional shoe, compared to the barefoot, **but only with steady arm support from a safety spotter**. **[See FIGURE 17 & VIDEO LINK]**

Again, if you try this test yourself, please note that, as shown, firm arm support for safety is absolutely necessary for anyone of any age to try this risky stability test wearing a conventional shoe sole. Again, a human spotter for safety support is absolutely necessary for a safe test.

Without safety support, you may sprain your ankle or break it or much worse!!! Do NOT ever try to do this test if you are frail or disabled in any way!

SCIENCE THIS BASIC IS ASTONISHINGLY RARE TODAY: A SIMPLE EMPIRICAL TEST WITH RESULTS THAT ARE BOTH RADICALLY DIFFERENT AND EASILY REPLICABLE

The twisted ankle of the human foot while in a shoe is grossly unstable and highly painful! The difference between that and the pain-free foot stability of the foot while bare is unusually large, as this remarkably simple test demonstrates clearly. In fact, the difference is truly black and white, with no real gray area between the two stability condictions. A discovery based on that stark difference is an extraordinarily rare occurrence in modern science, where finding a small but measurable and statistically significant difference is the only realistic research goal.

Moreover, the science here is at such a basic, if not rudimentary, level that the stability difference is not open to question in any serious way. It is a night and day empirical difference unheard of in modern scientific testing. The yardstick used here is based on the simplest electrical light switch with only two positions, on and off. The difference measured in the lateral ankle spraining position shown here is equally simple, stable barefoot and unstable shod.

This is definitely not rocket science. Anyone can experience and understand the glaring difference in stability. It is science at its simplest and most basic level. Unlike typical laboratory test results, the **Standing Ankle Sprain Simulation Test** is so simple it probably is not necessary to verify it in a formal randomized controlled trial (RCT) – the gold standard of modern science. But it should be easy to do so, although the blinding of test administrators might present some difficulty.

It is hard to imagine a different outcome is possible. Nevertheless, it would be possible to conduct a RCT without difficulty to completely eliminate a placebo effect. The one variation I have found in preliminary testing is that test subjects with undamaged ankle joint ligaments can hold an unstable tipping point position while standing in a conventional shoe sole that is tilted outward, whereas test subjects with ankle joints damaged from prior sprains are not be able to do so. The stability difference will be investigated in greater detail later, relative to FIGURES 39A-39F.

It is important to repeat here that the **SASS Test results could not be easier to replicate.** This provides a critically important contrast with other test results in modern science, which generally is in what has been called a **"replication crisis."** Most studies are never replicated to verify their results. Too many important research studies cannot be replicated by other researchers who try to do so. Consequently, that research should never have been published in the first place, since its results may be false.[16]

Worse, most modern research studies require specialist scientists and well-equipped labs to perform, and are sufficiently complex and difficult that the financial and time cost of replication is a very high bar to doing so. Moreover, there is very little incentive for researchers to repeat studies that have already been done, since there is little professional benefit in doing so.

In contrast, replicating **SASS Test** results is simple and easy, with almost no time or financial cost, and perhaps with no need to do so, since the test results are so dramatically different. Nevertheless, some scientists are so doctrinaire that they cannot believe their own eyes, but instead must rely for verification only on measurement in a laboratory with sophisticated digital equipment. Moreover, beyond its firm empirical basis, an equally simple theoretical analysis of the basic biomechanics of the SASS Test also appears to be irrefutable, as you will see in the next section,.

Besides the "replication crisis," **outright fraud** is also a problem in modern science, especially when there is a direct conflict of interest involved.[17] However, the **SASS Test** results are so simple and direct, so completely transparent, and so easily replicated by many thousands of individual test subjects, that the potential for fraud would seem to be non-existent.

It is simply apparent beyond any reasonable doubt that the modern foot is naturally stable when bare in the maximally tilted position of lateral ankle sprains, whereas the same foot when in a conventional shoe sole is artificially unstable. The rigid conventional modern shoe sole functions as an unnatural lever between the sole of your foot and the ground, a lever that creates a powerful torque that rolls your foot over. Almost half of the heel of the foot is hanging off the edge of the tilted conventional shoe sole, completely without structural sole support, only the support provided by the ligaments and tendons of the wearer's ankle.

In contrast, my **earliest prototype [FIGURE 18]**, circa 1990, even though primitive, mirrors much more closely the stable flattened heel of the barefoot when tilted into the maximum supination position.

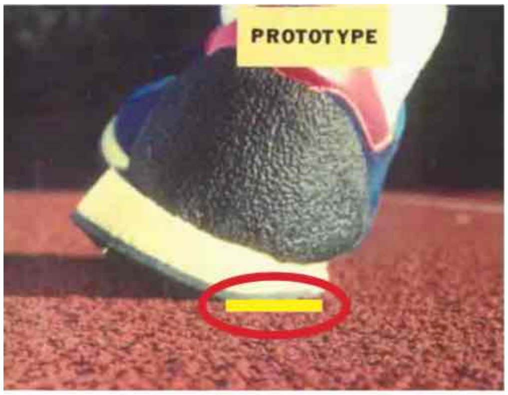


FIG. 18

The prototype has a sole with relatively deep sipes (in the form of slits) which demonstrates conclusively that the rigidity of conventional shoe soles is just a design option to which conventional footwear all default, in part because it is the easiest to make. It is certainly <u>not</u> an unavoidable requirement that is dictated by some unyielding law of structural or material mechanics. It is just an option, and the worst one.

THE BAREFOOT'S <u>NATURALLY</u> ALIGNED FORCES IN STABLE EQUILIBRIUM VERSUS THE SHOE'S <u>ARTIFICIAL</u> FORCE MISALIGNMENT AND DESTABILIZING TORQUE

When the **tilted foot is shown in cross-section** in the lateral ankle spraining position, the shoe sole's structural problem becomes even more clear **[FIGURE 19]**. The substantial tilting of the relatively rigid conventional shoe sole tends to force the wearer's foot to slide down to the outside, focusing the downward force of the body weight load onto the lateral edge of the shoe sole. The ground reaction force pushes up in a fixed position against the lateral edge of the shoe sole. The two forces are misaligned. That creates a fixed axis of rotation for the lateral shoe sole edge, which forms an artificial lever arm (the blue line between black arrows) creating an unnatural rotational torque powered by the downward force of the wearer's body weight located at the other end of the lever arm. The resulting artificial torque rolls the foot over, straining or breaking the ligaments and/or bones of the wearer's ankle.

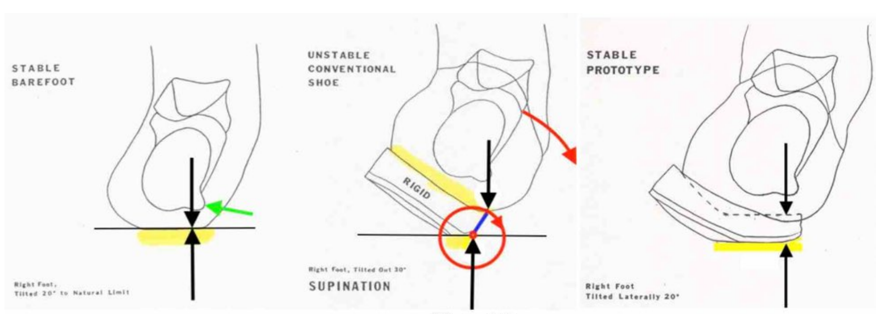


Fig. 19

In contrast, in the barefoot and early prototype the ground reaction force and body weight force are aligned, perfectly opposing each other directly in stable equilibrium, so no unnatural rotational torque is created between the flexible sole and the ground to artificially destabilize the foot. Moreover, the inverted barefoot is partially stabilized by a calcaneal tuberosity (marked by the **green arrow**) that provides some lateral structural support on the flat ground, unlike the inverted shod foot.

THE 1993 FUNCTIONAL PROTOTYPE OF AN ATHLETIC SHOE

Based on this clear understanding of the inherent structural problem of a conventional shoe sole, shown in **FIGURE 20**, it was possible for me in 1993 to design and develop a rudimentary **functional prototype athletic shoe sole**, shown in **FIGURE 21** **(**as well as earlier in **FIGURES 6A-E**), based on the barefoot sole (the figures are shown in the maximum supination position used in the **Standing Ankle Sprain Simulation Test**). I had to use unconventional means to build the prototype. Several prior "unofficial" attempts to construct a prototype based on my design had been made in Asian factories by potential licensees that I was in talks with, but, being professional footwear specialists, they corrected my unusual design to make it conventional and therefore useless as a true prototype (they were essentially like **FIGURE 59**, with a conventionally narrow but thick midsole and a wide but thin bottom sole wrapped up around the sides**).**

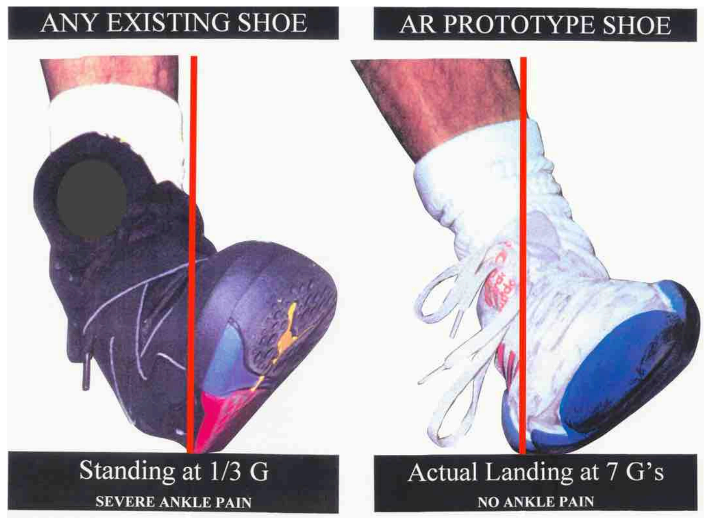


Fig. 20 **Fig. 21**

So, to actually get my unconventional prototype design made, I decided not to have it constructed by athletic shoe experts, but instead by someone with no footwear experience. I ended up going to John Nelson, a commercial toy designer in New Jersey, principally because he had no preconceived notions about how a shoe sole should be designed or constructed, but was a highly skilled model builder. I initially insisted on trying a computer design system approach, but it failed due to hardware limitations (processors from the Intel 286 era) that made it impossible to model the human foot's complex shape with its highly irregular geometry. Consequently, John was forced to rely on primitive pre-digital toy-making methods and model-making materials.

Instead of a shoe last, the shape of the inner surface of the prototype sole was determined by a plaster cast of my right foot that was prepared by a podiatrist. The sole included three components: outsole, midsole and insole, all three made out of flexible plastic, the insole of foamed flexible plastic. **[FIGURE 21A]**

FIG. 21A


Each was cast in a separate mold and the bottom and midsole were glued together. I mated those two sole components with a shoe upper taken from a track racing-type shoe (its thin sole having been removed using a heat lamp). I then used a sock filled with dried peas as a shoe last shaped with a rounded foot sole with a fully rounded lower surface from heel to toe (instead of the flat lower heel surface of a conventional last), which was necessary to be able to accurately glue the curved prototype sole to the curved fully lasted upper. In the last step, the insole was inserted into the shoe upper.

Despite being the product of such rudimentary and non-traditional footwear construction techniques, as well as lacking a bottom sole tread pattern (which was too much added cost and complexity), the barefoot sole-based prototype worked very well in achieving its principal goal. It eliminated the structural instability of the conventional shoe sole. In the typical ankle spraining position of maximum supination, the center of the ankle joint and the body weight force transmitted through it are located directly over the shoe sole that is in direct contact with the ground. No unnatural torque is created and the wearer's tilted foot remains stable, without ankle pain.

THE PROTOTYPE PASSED A SEEMINGLY IMPOSSIBLE BIOMECHANICAL LAB TEST

In fact, as shown below, an unprecedented actual jump test done in 1993 at the biomechanics lab at the University of Massachusetts at Amherst run by Dr. Joe Hamill (recently President of the International Society of Biomechanics) under the direct supervision of Dr. Ned Frederick of Exeter Research (Nike's first Director of Research, as well as founding and current Editor of ***Footwear Science***).

One male test subject leaped as high as he could while standing and landed on a force plate without difficulty on a single prototype-shod foot in the tilted lateral ankle spraining position at **7 G's** without ankle pain. **[FIGURE 22 & VIDEO LINK]** (A "G" is the force of gravity generated by your bodyweight, BW, when standing).

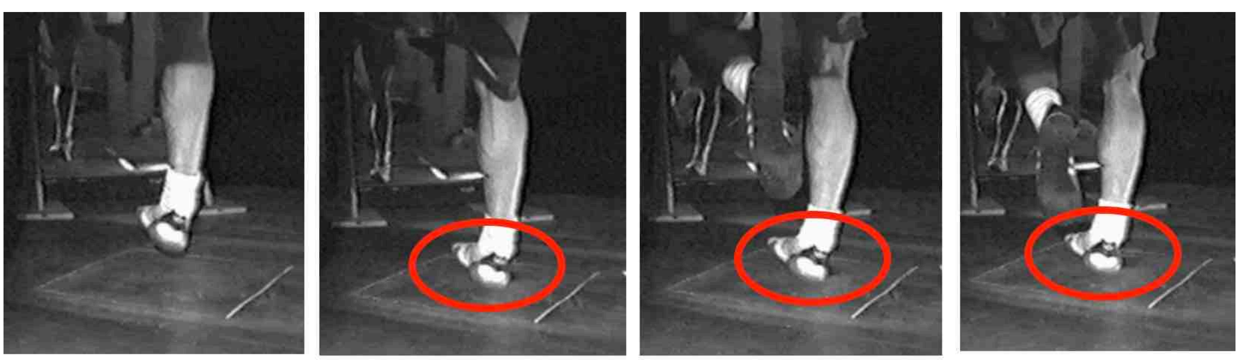


Fig. 22

Equally remarkable, a less robust male test subject who had a self-reported history of chronic ankle injuries still managed to do the same jump and landing on a single foot while maximally inverted in the prototype shoe at **4 G's**, also without ankle pain

By the way, although theoretically I would have liked to make a direct comparison between the prototype and a conventional shoe during this jump test, I am sure neither test subject would have volunteered to do it when wearing a conventional shoe while landing on a single foot in the lateral ankle spraining position. Actually, it never occurred to me to ask them to do it. I think it was obvious to all of us that attempting to do so would result in a badly sprained or broken ankle.

The test subjects were personally interested in the self-preservation of their ankles and I in the self-preservation of my extremely limited personal finances at the time, doubly so since I had no insurance that would cover any medical accidents occurring during the jump tests. There was no safety harness available in the lab, so a direct comparison was not possible in that test.

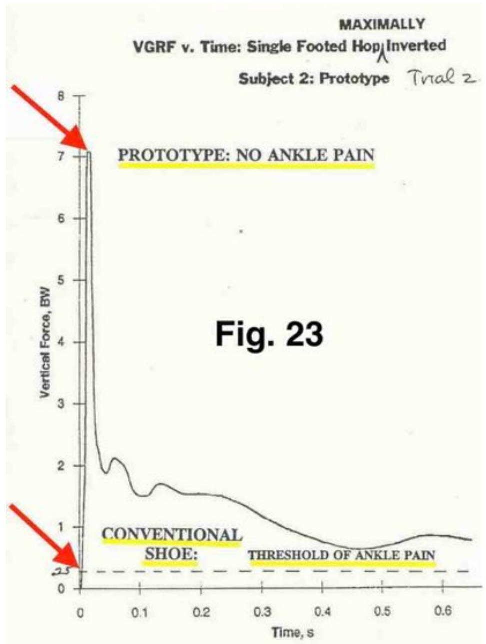


Fig. 23

Nevertheless, in a later static test when standing still and putting weight on a foot in a tilted conventional shoe in the lateral ankle spraining position, the physical reality is that a threshold of noticeable ankle pain is experienced at a controlled force of as little as 0.25 G.

Although somewhat subjective, I added that later standing test result to the bottom of the lab test report chart from Exeter Research shown in **FIGURE 23** and added the highlighted labelling to indicate graphically the enormous difference in stability performance.[18]

In comparison to standing, when walking or running the typical peak force is at least 1 to 3 G's, which explains why agonizing pain is experienced during an ankle sprain that occurs when running or even just walking.

THE SOLE OF THE SHOE ALONE, NOT THE UPPER, PROVIDES NATURAL ANKLE STABILITY

A critical stability issue in footwear design should be emphasized here. The typical example shown above in **FIGURE 20** of a very popular conventional basketball shoe with a hightop upper includes special straps that crisscross around the ankle to stabilize it against ankle sprains. As is obvious in **FIGURE 20** (a tilted conventional basketball shoe), hightop uppers and ankle straps do not prevent the basic sole instability causing ankle sprains in tilted conventional shoe soles.

The straps on the shoe upper are counterproductive anyway, since even if they were powerful enough to restrict the natural motion of the shod ankle, they would just transfer the ankle's motion and the resulting sprain or break up the leg to the knee. A knee injury would then result from unnaturally forcing the knee to move excessively to make up for lack of motion at the ankle! The hip could suffer in the same way. This is a well understood basic problem that applies generally to other traditional techniques to restrict ankle motion.[19]

Because hightop uppers and straps do not prevent ankle sprains, all basketball players at least at the NBA and NCAA level routinely get their **ankles heavily taped** before games, including Michael Jordan **[FIGURE 24]**. Nonetheless, ankle sprains occur frequently to these players, even to Jordan, the greatest player of all time, as shown in **FIGURE 35.**

These ineffective non-sole approaches include systems integrated into the shoe upper, like the Reebok ***Pump System*** **[FIGURE 25A]** of the 1990's and the recent Nike ***HyperAdapt 1.0 and 2.0***, with its electronically controlled lace-tightening engine.

There are also foot and ankle braces worn around the foot and ankle inside the shoe. Such **in-shoe systems** **[FIGURE 25B]** are generally considered the most effective ankle sprain prevention alternative currently available, but often fail, a fact of which you will later see convincing evidence here, while also inherently restricting natural ankle motion, potentially transferring excessive motion to the knee and hip.

NBA superstar Stephen Curry wears these in-shoe braces on both feet and ankles **[FIGURE 25C]**, as does budding all-star Trae Young, whose untimely lateral ankle sprain played a key role in the Atlanta Hawks' lost to the Milwaukee Bucks in the 2021 NBA Eastern Conference finals **[FIGURE 25D]**.

The real ankle stability problem is <u>exclusively</u> a conventional shoe <u>sole</u> problem. The shoe upper has nothing to do with causing it. To make this point at the time as emphatically as I could, my highly stable 1993 basketball prototype shoe (shown above in **FIGURE 21** next to the conventional shoe **FIGURE 20**) has a <u>lowtop shoe upper</u> taken from a sprint track shoe with no upper structure at all, leaving the wearer's ankle joint completely unsupported by the shoe upper. This design choice was made to demonstrate unequivocally that the shoe upper has nothing to do with ankle stability. The prototype sole design solves the ankle stability problem entirely with the barefoot sole design by itself.

Putting it another way, ankle straps and the many other conventional ankle stabilizing devices like ankle braces around the ankle itself function as nothing more than ineffectual Band-Aids® covering the gaping wound of needless ankle sprains actually caused by faulty shoe sole design. Nevertheless, hightops, upper straps, and other upper bracing systems continue to be used with conventional shoe sole designs by most if not all of the major athletic shoe companies.

Current basketball shoes are so unstable that hall-of-fame players like Chris Paul are forced to strengthen their ankles by practicing on a dynamically unstable balance beam before games, in this case an NBA Conference Final, as shown in **[FIGURE 25E & VIDEO LINK]**.

To summarize my footwear research: (1) the human barefoot is innately stable, even in the extreme supination position in which most ankle sprains occur, as can be easily verified by anyone (other than the frail or disabled). (2) Conventional shoe soles artificially make the shod human foot inherently unstable in the same extreme position, again as anyone not disabled or frail with a conventional shoe can verify (<u>but only with extreme caution</u>), thereby making unnatural ankle sprains and falls extraordinarily common. (3) My shoe sole prototype provided extraordinarily powerful evidence – indeed **conclusive proof of concept** – that the dramatic stability difference is due to a fundamental shoe sole design flaw that is correctable, thereby preventing nearly all ankle sprains and falls. Additional proof follows.

ALL CONVENTIONAL SHOES HAVE A <u>LUDICROUS MODE</u> THAT CAUSES UNNATURAL INSTABILITY

The unmistakable technology leader of the automotive industry, Tesla, reserves it famous software-based **Ludicrous Mode** as a top-of-the-line high tech feature for its most expensive cars. Unlike Tesla, the entire footwear industry includes a **Ludicrous Mode** feature in every shoe, even the cheapest, as a standard feature. You cannot avoid it.

Tesla uses the term **Ludicrous Mode** for hyperbolic effect to describe an almost absurd boost of extra acceleration provided by the feature that is on top of already extraordinary acceleration provided by instant max torque of its electrical engine compared to conventional internal combustion engines. In contrast, for the footwear industry, the Ludicrous Mode of conventional shoe soles unfortunately describes the standard structural design defect of the sole that causes its unnatural instability compared to the barefoot.

STANDING STATIC FOOTPRINT VERSUS MAXIMUM SUPINATION FOOTPRINT

So, what exactly is the basic problem with conventional shoe soles? As already mentioned, conventional shoe soles are made to fit the **standing or static footprint** of a wearer while immobile and standing in an upright position. However, modern mass market footwear is not good even at meeting this fairly simple design constraint. Most modern shoe soles, including athletic shoes, do not support the inside edge of the big toe or the outside edge of the 5th toe or the head and base of the 5th metatarsal bone. **[FIGURE 26]** This is a universal modern **mismatch problem** that has always existed, even in the 1980's for NBA superstars like Larry Bird, shown standing upright at ease. **[FIGURE 27]**

STATIC FOOTPRINT

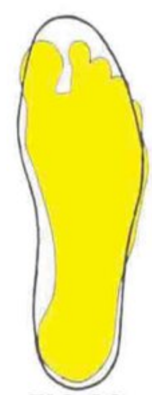


FIG.26

However, this mismatch problem is very minor compared to the much more significant problem of the wearer's foot rolling onto or entirely off the <u>outside edge of the upper surface</u> of the shoe sole, which risks or causes a lateral ankle sprain or break and fall. When the foot rolls as far as it can, as shown in **maximum supination footprint** (in yellow) **[FIGURE 28]** compared to the upper surface of a conventional shoe sole, a large part of the foot sole is unsupported by the upper surface of the conventional shoe sole. Only the shoe upper acting as a physical restraint keeps the foot from rolling off the conventional shoe sole.

MAXIMUM SUPINATION FOOTPRINT

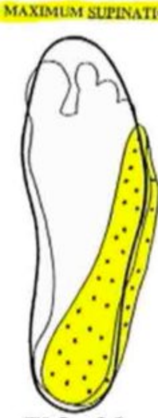


FIG. 28

2017 NBA AND NCAA BASKETBALL CHAMPIONSHIPS DECIDED BY ANKLE SPRAINS

Besides causing medical problems involving enormous pain and suffering for everyday shoe wearers, ankle sprains also often randomly determine important championships in major sports. In 2017, for example, a strong case can be made that both NBA and NCAA championships were won not by the better team, as it should be, but by chance alone, specifically by the lucky team whose best player did not happen to sprain his ankle.

In the NCAA championship semifinal game, Gonzaga's star player, Williams-Goss, sprained his right ankle and, in the final game, sprained it again, disabling him. With this assist from blind luck, Carolina won the national championship. **[FIGURES 29 & 30, & VIDEO LINKS]**

Similarly, in the 2017 NBA playoffs, San Antonio superstar Kawhi Leonard first sprained his left ankle in a Western Division Semi-Final game against Houston. In the first game of the Final Western Conference series at Golden State's home court, Kawhi totally dominated the game on both offense and defense, putting San Antonio ahead by more than twenty points, despite spraining his left ankle a second time.

However, a coup de grace was delivered by what was either an inadvertent or allegedly well-aimed opponent's foot, which sprained Kawhi's left ankle for a third and final time, taking him out of the first game with Golden State on their home court midway through the second half, after he had completely dominated them on both offense and defense. The third sprain was enough to take Kawhi out of the rest of the series, allowing Golden State to win the Western final and then onto a clear path to its next NBA title. **[FIGURES 31-33 & VIDEO LINKS]**

2018-2021 NBA BASKETBALL CHAMPIONSHIPS ALSO DETERMINED BY INJURIES, MOSTLY DUE TO SHOE SOLE INSTABILITY

In addition to 2017, it is reasonable to conclude that all of the NBA championships since have been won by the team that suffered the fewest random injuries to key players.[20] In 2018, it was a hamstring injury to Chris Paul of the Houston Rockets, allowing the Golden State Warriors to win. In 2019, it was the Achilles tendon rupture to Kevin Durant previously described relative to **FIGURES 6-8**, as well as Klay Thompson's torn ACL, allowing the Toronto Raptors to beat Golden State. In the COVID-shortened 2020 season, the Miami Heat lost two key starters before it lost to the LA Lakers.

In 2021, it has been much worse. It has been a virtual bloodbath. Ten NBA All-Stars and two budding all-stars could not appear in playoff games due to injuries and one due to a COVID protocol. The three teams favored to win the championship all lost due to injuries to their star players. The Utah Jazz was hampered by Mike Conley's hamstring injury and Donovan Mitchell's sprained ankle. The LA Lakers lost Anthony Davis to a groin injury (probably initiated by an earlier ankle sprain). The favorite team, the Brooklyn Nets, lost James Harden to a hamstring injury and Kyrie Irving to a lateral ankle sprain, leaving only Kevin Durant. Another championship favorite, the LA Clippers, lost Kawhi Leonard to an ACL injury.

The Atlanta Hawks lost Trae Young to a lateral ankle sprain.

In the Eastern Conference final series, the Milwaukee Bucks lost two-time NBA MVP Giannis Antetokounmpo, the "Greek Freak" of nature, for several games due to a hyperextended knee. Although another player's leg forced Giannis' leg to the outside into a laterally tilted, ankle spraining position, his shoe sole offered no resistance or direct support. Only his nearly miraculous recovery enabled the Bucks to win the NBA title. **[FIGURES 33A&B & VIDEO LINKS]**

In short, instead of the best team winning the 2021 NBA championship, once again the winner was just the luckiest team in terms of avoiding injury that kept its key stars from playing:

> Groins. Hamstrings. Knees. Feet. The injuries that can fill a medical textbook have blurred the league's championship picture, distorted the long-term futures of teams and turned the playoffs into a basketball war of attrition.[20]

The dominance of injuries in determining championships is a trend that seems to have been growing in strength in recent decades. Is it related to changes in shoe sole design?

SHOE SOLE-INDUCED ANKLE INSTABILITY HAS PROGRESSIVELY GOTTEN WORSE

The examples of ankle spraining previously shown highlight an interesting contrast. All of the sprain examples shown prior to Kawhi's occurred without the wearer's foot being pushed into an unstable ankle spraining position by an outside force, most typically by inadvertently stepping on another player's foot, as happened to Kawhi. Through a combination of new design factors, including higher heel lifts and softer sole materials, by the 1990's the athletic shoes had become significantly more unstable, as pointed out by famous Celtic coach and general manager Red Auerbach.

In the past, most ankle sprains have been initiated in the same way as did those of Kawhi Leonard, by stepping on another foot. However, that obstacle as a biomechanical triggering mechanism is unnecessary in the performance athletic shoes of today, which have become progressively more unstable than those in the 1990's. Their inherent structural instability, by itself, can create an entire ankle sprain sequence from beginning to end without any outside trigger. Unbelievably, it is even possible now to rollover both ankles at the same time without a triggering mechanism other than the shoe sole. **[FIGURE 34 & VIDEO LINK]**

As a result of the fundamentally flawed design of conventional shoe soles, all of the greatest NBA players, without exception, have fallen prey to ankle sprains, including **Michael Jordan [FIGURE 35], LeBron James [FIGURE 36]** and **Stephen Curry [FIGURE 37 & VIDEO LINK]**.

In addition, these star NBA players are shown in a gallery just as their lateral ankle sprains occurred before or during the 2021 playoffs. Included are 2019-20 NBA MVP Giannis Antetokounmpo (before), Anthony Davis (just before), and (during) Kyrie Irving, 2021 NBA MVP Nicola Jovic, Russell Westbrook, and Trae Young, who probably was the first NBA player to have been seriously injured during a playoff game by stepping on one of the officials calling the game. **[FIGURES 37A-F & VIDEO LINK]**.

All of those sprains were unnaturally unavoidable in conventional shoe soles, even when the best available anti-ankle sprain device was used, as demonstrated by Curry and Young. They both were wearing state-of-the-art ankle braces on their badly sprained right ankles shown here (their ankle braces appear to be the same as the in-shoe brace shown earlier in **FIGURES 25B-D**). Curry has been plagued during his NBA career by ankle sprains, resulting in two surgeries on his right ankle.

ALL OTHER COURT SPORTS SHOES ARE JUST AS UNSTABLE

To take just one example among a great many, Serena Williams, perhaps the greatest female tennis player of all time, is shown here rolling her ankle in the 2019 U.S. Open. There are countless other examples. **[FIGURE 37G & VIDEO LINK]**.

REMOVING THE SHOE UPPER REVEALS THE REAL PROBLEM WITH CONVENTIONAL SOLES

Shoe uppers perversely disguise what the actual dominant role of the sole during an ankle sprain in a conventional shoe. Since it is firmly attached to the sides of the shoe sole, the shoe upper keeps the wearer's foot locked in a position that is centered more or less on top of the shoe sole.

Removing the shoe upper of a conventional shoe allows an unobstructed view of what is actually happening in a lateral ankle sprain. Only the coefficient of friction keeps the bare foot on the shoe sole. (If you want to try it, cutting the shoe upper off is fairly easy to do if there is not any hard plastic, like a robust heel counter. You can often do it easily, just be careful with whatever sharp instrument you use to cut.)

As shown here, the bare foot is centered in a position on top of a shoe sole with no upper. The foot is rolled slowly to the outside, gradually moving into the maximum supination position. <u>What is amazing to understand here is that this fully supinated foot is simply in a normal position within the normal range of motion allowed by the subtalar joint.</u>

(1) When the outside edge of the little toe and the head and base of the 5th metatarsal bone have rolled over the outside edge of the shoe sole, the example shoe sole is tilted forcibly

tilted thereby into an unstable position of about 20° of lateral tilt of the shoe sole. This is the classic literal **tipping point** at which the wearer can tenuously maintain balance only by very careful control of muscles, tendons, and ligaments that maintain the foot and ankle balanced on a tiny knife-edge of structural support provided by the shoe sole.

(2) As the foot sole continues to roll to the outside into the maximum supination position, the lateral forefoot and midfoot bones roll entirely off the shoe sole, forcing it into 40° of lateral tilt. Unrestrained by a shoe upper, the lateral force on the forefoot and midfoot bones exceeds the coefficient of friction hold them on the shoe sole. As a result, they slide off the shoe sole, although the heel of the foot moves only slightly, remaining positioned on the shoe sole heel.

(3) Finally, as the lateral force on the foot heel exceeds its coefficient of friction, the heel follows out of control, sliding almost entirely off the shoe sole and forcing the unattached shoe sole into a 50° lateral tilt. **[FIGURE 38A & VIDEO LINK]**

Fig. 38A

In an underneath view through a clear Plexiglass surface, you can see the highly unstable initial tilted position of the lateral ankle sprain position, with only the white line of a knife edge of a conventional shoe sole making direct contact with the ground. Both outside edges of the head and base of the 5th metatarsal bone are clearly poised over the outside edge of the upper surface of the shoe sole, unsupported by either the shoe sole or the Plexiglass surface.

In the final position, the bare foot has rolled almost entirely off the shoe sole, and the foot's calcaneus and base and head of the 5th metatarsal bone are making direct, load-bearing contact, indicated by the large white areas on the Plexiglass surface. Again, by removing the shoe upper, the actual three-part interaction between bare foot, shoe sole, and ground is clearly revealed. The biomechanical fact demonstrated is that the conventional shoe sole is simply too narrow to support the foot sole through it normal full range of motion from maximum supination to maximum pronation. [**FIGURE 38B** & VIDEO LINK]

Fig. 38B

If you are very careful, you can generally replicate these results without difficulty by cutting off the upper of one of an old pair of conventional shoes, preferably with a soft fabric material upper. All you need is a sturdy pair of sharp scissors or a craft knife. You can compare one shoe with an upper with the same shoe sole with upper removed.

THE ARTIFICIAL MISALIGNMENT OF STATIC FORCES ON THE ANKLE JOINT OF SHOD FEET

Analyzing the opposing forces on the ankle joint when stationary is another excellent way to understand the fundamental difference between ankle stability in a shoe sole and when barefoot. This is physics at its simplest and most basic.

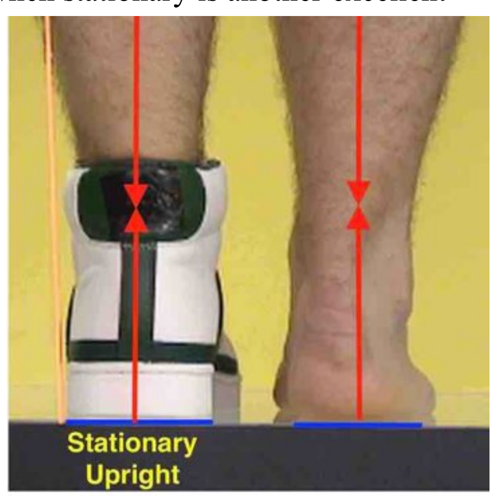


Fig. 39A

Standing Equilibrium: When standing **upright and stationary**, with feet close together and flat on the ground, both bare and shod foot are stable, with the downward force of the test subject's body weight (BW) in firmly balanced alignment with the matching upward ground reaction force (GRF) in stable equilibrium.

Both BW and GRF opposing forces are aligned with the bone structures of the lower leg, ankle, and heel (tibia & fibula, talus, and calcaneus, shown later in

FIGURE 48). The alignment allows both forces to be supported through the compression of the bones, for which the structural design of bone is optimized. (**FIGURE 39A**)

Initial Stabilizing Ankle Torque: As the shod foot is rotated outward into a **10° outward tilted** position, the relatively rigid shoe sole breaks contract with its entire supporting surface, except for the lateral or outer edge.

The entire body weight is shifted outward onto a knife-edge of support, which locks that edge against the support surface, creating an artificial center of rotation located at the edge. The ground reaction force is thereby focused upward exclusively at that outer sole edge. However, the downward body weight force remains centered on the middle of the ankle joint, so a stabilizing torque or force moment is created that acts to push the shod foot shod back toward the support surface. Although BW and GRF opposing forces are no longer directly aligned, the misalignment creates an inward, stabilizing torque against outward tipping of the shoe sole.

The wider the shoe sole, the greater the stabilizing torque, but also the more cumbersome, since extra wide conventional shoe sole have an inherent dysfunctional "snowshoe" effect.

In contrast, when tilted 10° the bare foot retains a very wide base of support flat on the ground, particularly at the heel, with body weight and ground reaction forces in balanced alignment. (**FIGURE 39B**)

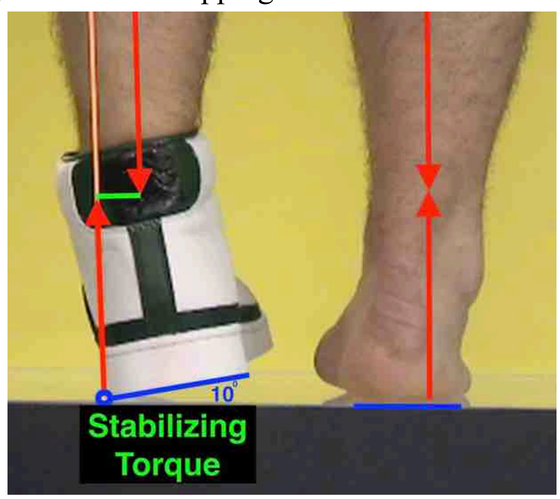


Fig. 39B

The Tipping Point: As the shod foot is rotated further outward into about a **20° outward tilted** position, the two opposing forces come into a tenuous alignment, balanced on a literal knife-edge tipping point. Movement outward or inward from the tipping point moves the opposing forces out of alignment, causing an inward or outward torque or force moment. The angle of the tipping point varies between individuals and shoe widths.

Only the shoe wearer's ligaments and tendons around the ankle joint provide structural support to it. Critically, only shoe wearers with relatively undamaged ankle joint ligaments can hold the tipping point position while standing, whereas those wearers with ankle joints damaged from prior sprains, which are quite common, are often not able to do so.

Again, in contrast, the barefoot in the same 20° outward tilted position maintains a wide base of contact while flat on the ground, particularly at the heel, with the BW and GRF opposing forces in firmly balanced alignment with the bones of the lower leg, ankle, and heel (as shown later in the Supination position of FIGURE 48), which provide strong and steady support under the compression of the aligned forces. No misalignment or torque is created when the outward angle of tilt of the barefoot increases. (**FIGURE 39C**)

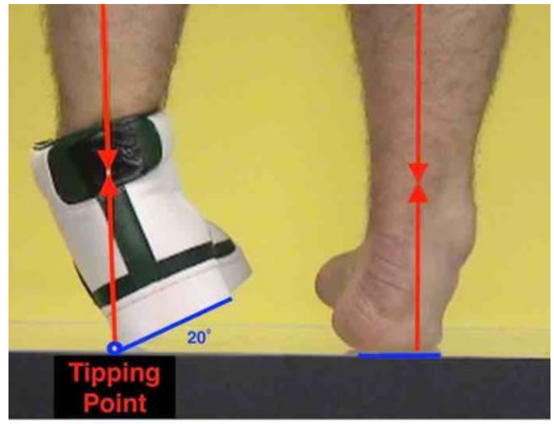


Fig. 39C

Final Destabilizing Torque: As the shod foot continues to rotate further outward into about a **45° outward tilted** position, the two opposing forces move out of alignment, creating a destabilizing torque or force moment. The farther to the outside the tilting occurs, which can and does continue through 90°, the greater the misalignment and the more powerful the destabilizing torque. Once more, only the shoe wearer's ligaments and tendons around the ankle joint provide structural support to it, instead of a natural structural alignment of bones with the BW and GRF opposing forces.

In continued contrast, the barefoot does not move beyond its maximum supination position and retains a reduced but still wide base of ground contact at the heel with opposing forces always remaining in steady balance flat on the ground. The bones of the lower leg, ankle, and heel are in direct structural alignment, thereby restraining loads and tension on the ankle's ligaments and tendons, keeping them well within normal limits, so the ankle is stable. (**FIGURE 39D & VIDEO**)

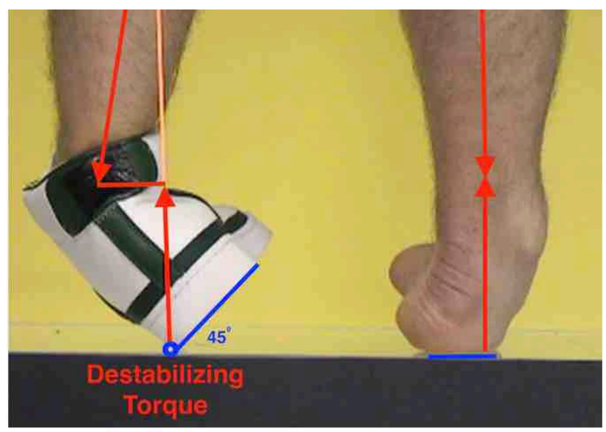


Fig. 39D

Summary of the stark stability difference: in the bare foot the ankle joint is naturally stable because the opposing BW and GRF forces on it are always directly aligned in balanced equilibrium. The opposing forces are always fully supported by lower leg, ankle, and heel bones throughout the foot's range of motion, especially including extreme supination and pronation.

However, in the shod foot the ankle joint is artificially unstable when the shoe sole is in a tilted position during extreme supination and pronation because the opposing BW and GRF forces cannot be in alignment, thereby creating artificial destabilizing torque on the ankle joint. Only the shoe wearer's ligaments and tendons surrounding the ankle joint can provide any direct support to it to counteract the unnatural torque; the tibia & fibula, talus, and calcaneus bones cannot provide direct structural bone support to the ankle joint due to their tilted misalignment.

AN EXTERNAL ANKLE ADDUCTION MOMENT (AAM) IS POWERFUL DURING MOTION

External **knee adduction moment (KAM)** in the human knee is an important research focus in biomechanics and orthopedics, principally because of the correlation of elevated KAM with osteoarthritis of the knee. A similar external **ankle adduction moment (AAM)** exists in the human ankle, although it is much smaller in the standing upright position, so it has received little attention in existing research.

However, when the foot is moved away from the centerline of the body, the ground reaction force rotates from vertical to angled toward the centerline. Moreover, during walking and running and in sports, the ground reaction force also rotates toward the centerline even more, especially in reaction to sharp cutting motions in sports, in which a strong horizontal traction component of the ground reaction force becomes an important factor in powerfully forcing the foot laterally.

As the result of human body's lateral motion, when the shod foot is forced into the same **20° tilt** during maximum supination shown above as the **Tipping Point** (FIGURE 39C), the internal rotation of the ground reaction force creates an external ankle adduction moment (AAM) or torque (the blue arrow), as shown in **FIGURE 39E**, that is as great or greater than the destabilizing torque shown in FIGURE 39C.

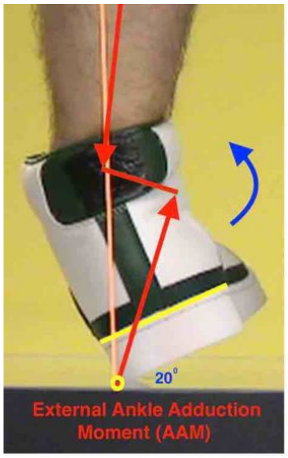


Fig. 39E

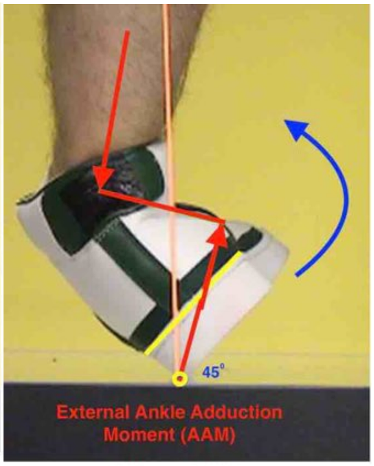


Fig. 39F

Worse, when the shod foot of a moving human body is forced into the same **45° tilt** shown above as Destabilizing Torque (**FIGURE 39D**), even with the same moderate ground reaction force, an external ankle adduction moment (AAM) or torque (blue arrow) is created that is twice as large or larger than the destabilizing torque when the wearer is stationary. (**FIGURE 39F & VIDEO**)

If the human body in motion causes the body weight and ground reaction forces to become much greater, such as in the 7 G leaping example shown in FIGURE 22, then the external ankle adduction moment (AAM) becomes correspondingly much greater. The extreme tilted position of the shod foot becomes uncontrollable by the shoe wearer, typically causing the ankle to sprain or break. Any misstep, especially stepping on another player's foot during sports, can force the shod foot into a similarly exaggerated tilt that is uncontrollable by the shoe wearer due to the powerful AAM created by opposing forces at a multiple G level.

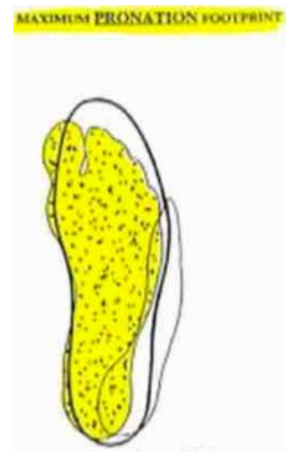


FIG. 40

MAXIMUM PRONATION FOOTPRINT IS ALSO A MISMATCH WITH EXISTING SHOE SOLES

Just as there was a substantial mismatch between the upper surface of a conventional shoe sole and the maximum supination position of the foot, there is the same kind of mismatch between shoe sole and the **maximum pronation position** of the foot. **[FIGURE 40]**

The foot tends to roll onto or over the inside (or medial) edge of the shoe sole's upper surface, unnaturally destabilizing it by causing an inward tilt. This artificial inward tilt can be relatively minor in conjunction with a single normal cutting or pivoting motion without injury, as shown here with a right foot. **[FIGURE 41]**

The inward tilt can be extreme, which can occur in shoe wearers who tend to pronate excessively, usually without an acute injury, as shown here in a left foot. **[FIGURE 42]**

However, when the inward rolling motion is more extreme, so that the shoe sole tilts inward out of control, the resulting instability seems to explain the existing epidemic of acute knee injuries, particularly among female athletes like **Becky Hammon**, whose anterior cruciate ligament (ACL) tear is shown in the position it occurred, demonstrating that the big toe and forefoot have rolled over and off the inside edge of the right shoe sole. **[FIGURE 43A & VIDEO LINK]**

However, this is an end-stage position that is first initiated by her foot rolling off the outside edge, like Jamal Murray's (FIGURES 11A & 11B), **[FIGURE 43B & VIDEO LINK]** Therefore, Becky Hammon's subtalar joint is shown moving instantaneously from extreme supination to extreme pronation, causing a parallel extreme rotation of her shin or tibia, twisting it suddenly and unnaturally against her thigh bone or femur, overstressing the ACL of her knee. Again, the alternative explanation is that it just happens.

A Division 1 college basketball player is shown injuring his left knee during the 2019 NCAA tournament. **[FIGURE 44 & VIDEO LINK]**

In addition, **Stephen Curry** is also shown demonstrating that in-shoe ankle braces (which he wears on both feet) fail to prevent the medial stability problem in the inward direction, causing uncontrolled internal foot and shoe tilting and associated knee problems, just they were shown previously failing to prevent Curry's severe lateral ankle sprain. **[FIGURE 45 & VIDEO LINK]**

NARROW SHOE SOLE CAUSES EXCESSIVE PRONATION WITH EACH RUNNING STRIDE

On the other hand (or foot, as it were), with conventional shoe soles the inward pronation tilt can occur with every running stride, again, particularly with runners who tend to pronate excessively. In contrast, the same pronating runners do <u>not</u> pronate when running barefoot (shown at the same point of maximum pronation). **[FIGURE 46 & 47]**

As is clear in the barefoot and shod photographs taken of the same "pronator" type female runner at approximately peak load midstance, the runner's ankle joint is essentially upright, whereas it is tilted inward in a conventional running shoe. Note also the (circled) unnatural fibula bone bulge on the outside of the ankle joint of the running shod foot which is not present in the running bare foot in the same midstance position.

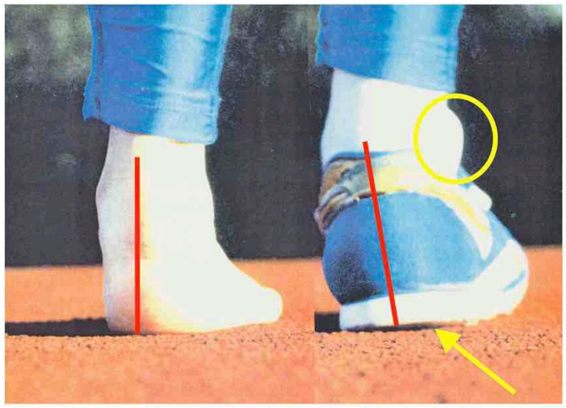


Fig. 46

Fig. 47

In addition, the runner's entire barefoot sole is contacting the ground, including the lateral edge, while in contrast a major portion of the lateral side of the shoe sole, particularly in the shoe heel area, is not contacting the ground due to the inward tilt of the shoe sole caused by the runner's foot rolling onto the shoe sole's inner edge.

This major stability difference between the shod foot and the bare foot when running is not new information. The same general observation about artificial shod pronation (and shod take-off supination) during running was made in 1986 by Dr. Benno Nigg, one of the leading pioneers of modern human locomotion biomechanics. Dr. Nigg noted that:

> The results of several thousand foot contacts analyzed over the last 12 years showed that a runner pronates more running with running shoes than running barefoot, and that over pronation frequently occurs. …Athletes with pronation values of more than 30° are not unusual…. What you can see with respect to pronation and overpronation is shocking. Some runners give the impression that **they are standing beside their shoes!** [bolding added]

Take-off supination means a rolling over the outside of the forefoot during take-off. Most runners do not do that running barefoot. However, many of the shoes produce some take-off supination which may be 20° to 25°.[21]

What has always been missing in such past observations of over-pronation and over-supination during shod running is an understanding of what specifically caused the vast side-to-side stability difference between bare feet and feet shod by footwear soles. Since shoe soles have always been that way, the defect was apparently so fundamental it remained well hidden in plain sight.

THE COMPLETE RANGE OF MOTION OF THE SUBTALAR JOINT

The fundamental stability problem is that the dynamic footprint your foot makes on the ground throughout the full normal range of its lateral or side-to-side range of motion (R.O.M.) is much wider than the static footprint conventionally used to make shoe soles. The subtalar joint, located immediately below the ankle joint, allows the foot to move from a typical maximum internal motion of about 10° of pronation to a typical maximum external motion of about 20° of supination, as summarized in this chart showing calcaneal eversion/inversion. **[FIGURE 48]**

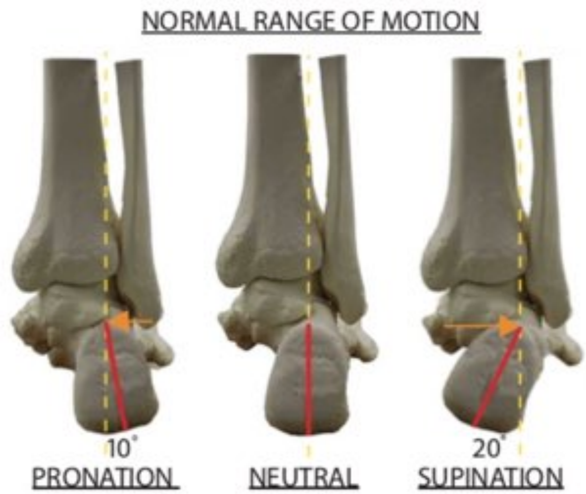


FIG. 48

While this figure illustrates the conventional wisdom for many years, it has since been measured more accurately. The human subtalar joint has an average clinical range of supination motion of about 25°-30° as measured in calcaneal inversion, as well as pronation motion of about 5-10° in calcaneal eversion.[22]

THE DYNAMIC FOOTPRINT IS MUCH WIDER THAN CONVENTIONAL SHOE SOLE

What that wide range, 30°- 40°, of subtalar joint motion means is that your foot simply tends to roll onto the inner or outer edge of the upper surface of the conventional shoe sole when your foot becomes substantially pronated or supinated during locomotion. It is as simple as that.

Perhaps more important, when your foot becomes maximally pronated or supinated, your foot rolls off the surface of the shoe sole so that it is without direct structural support underneath it and therefore falls out of control, restrained only by the shoe upper, pivoting around the lever that is formed by the edge of the shoe sole.

Fig. 49

The **dynamic footprint** of a typical shoe wearer shown in FIGURE 49 is a combination of a maximum pronation and supination footprints, superimposed on the outline of a conventional shoe sole. The pronation footprint has an outside part (shown on the left side, highlighted in yellow) that is unsupported by the structure of the conventional shoe sole. The pronation footprint is overlapped by a maximum supination footprint, which also has an outside part (shown on the right side in yellow) also unsupported by the conventional sole structure.

Together, the merged footprints show the full range of the foot on the ground that is allowed by the subtalar joint as the foot rolls sideways as far as it can go in either direction. The conventional shoe sole is much too narrow to provide structural support to either outside part of the dynamic footprint.

The example dynamic footprint of FIGURE 49 is of a typical shoe wearer whose pronated foot can essentially roll onto or entirely off the inside or medial edge of the upper surface of the shoe sole, restrained only by the shoe upper. More typical is the problem of rolling onto or entirely off the outside or lateral edge of the upper surface of the shoe sole. In either case, that unsupported sideways motion inherently creates foot and ankle instability that can cause an ankle sprain or break or fall.

Most critically, the essential ground-contacting bone structures of the foot must be directly supported by the upper surface structure of the shoe sole throughout the full range of normal pronation and supination motion allowed by the subtalar joint. **[FIGURES 51 & 50]** This is basic structural architecture at its most fundamental level.

Just as a good foundation is essential to support all of the main structural elements of any building, a shoe sole must support the medial and lateral bones of the foot in their full range of motion. As seen in FIGURE 51, located on the medial or inside of the foot are the calcaneus or heel bone, the head of the 1^{st} metatarsal bone, and the 1^{st} distal phalange (or big toe). On the lateral or outside of the foot are the lateral calcaneal tuberosity, the base and head of the 5^{th} metatarsal bone, and the 5^{th} distal phalange (or little toe). These are the essential ground-contacting bones of the foot.

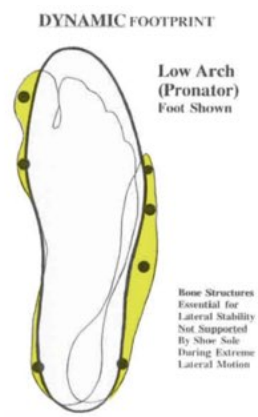


FIG. 50

FIG. 51

A SHOE SOLE THAT IS WIDE ENOUGH TO FIT THE DYNAMIC FOOTPRINT SOLVES THE TOO NARROW PROBLEM, BUT CREATES ANOTHER

Solving the basic mismatch problem between narrow shoe sole and wide dynamic footprint is theoretically simple. The shoe sole just must be as wide as the dynamic footprint **[FIGURE 52]**, thereby supporting the full range of the foot's side-to-side motion from extreme supination through extreme pronation of the subtalar joint.


FIG. 52

As a practical matter, a real-world solution is more complicated. For example, in the mid 1970's, Nike introduced a running shoe, the **LD-1000** **[FIGURE 53]**, which had a "super-wide" sole, particularly at the heel. The main problem with the **LD-1000** was that the sole was extremely flared, so that the shoe sole was much wider only at the bottom, but not at the top,

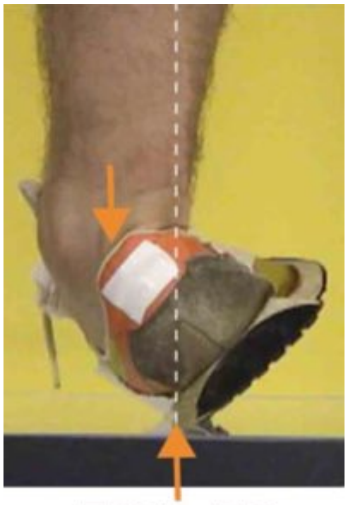


FIG. 53

which still was formed to fit the sides of a standing or static footprint, so the wearer's foot easily rolls off the outside edge of the upper surface of the shoe sole, just like any other conventional shoe sole.

The **LD-1000** apparently caused sufficient problems for enough runners that it was abruptly withdrawn from production and replaced by a narrower running shoe, the **LDV**, with much less flare to the sides, as was conventional then. A new version of the same basic design approach is the Hoka One One **TenNine**, which has a heel area with a very wide rear extension that severely limits its use to road running and almost nothing else. **[FIGURE 54]**

At least from the experience of the **LD-1000** it is clear that both upper and lower shoe sole surfaces must be sufficiently wide to provide direct structural support to the wide dynamic footprint made by the wearer's foot sole. However, it is clear that extra width alone is not enough to make a practical shoe sole.

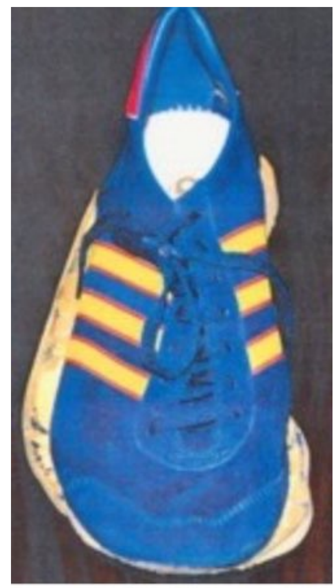


Fig. 55

Imagine trying to run normally in a pair of running shoes constructed like those I made in the late 1980's as a design exercise to illustrate the obvious problem of very wide shoe soles **[FIGURE 55]**. Running in them is kind of like running awkwardly in snowshoes but without the snow. In addition, in an active sport like basketball, they would cause continual problems with the wearer or others stepping on the extra wide sides.

Besides the obvious practical problems of this design, it illustrates the principal conceptual problem of conventional shoe soles. It is that the shoe sole is conceived of as flat, cookie-cutter section of the ground that is attached to the shoe upper, the upper being the only part of the shoe that is contoured to the rounded shape the wearer's foot.

A fundamental paradigm shift in basic design is unavoidable if the stability problem is to be fixed. **To function naturally, the shoe sole must be understood as an extension of the wearer's foot sole**, not as a transportable extension of the flat ground. The distinction cannot be more basic than that!

A NATURAL SHOE SOLE IS A WIDE EXTENSION OF THE FULLY ROUNDED AND FLEXIBLE FOOT SOLE, INCLUDING THE ROUNDED FOOT HEEL

Shoe soles need to be as **wide as the dynamic footprint** of a wearer's foot sole, but also should be structured as extensions of the wearer's curved foot sole, not flat sections of the ground. Therefore, the extra wide sides of a natural shoe sole must be rounded, wrapping up around the curved sides of the wearer's naturally rounded foot sole.

In addition, to avoid a destabilizing rocking-chair effect caused by the rounded sides of a natural shoe sole, it needs to be sufficiently **flexible** to flatten by deforming under the body weight load of the wearer, when the wearer's foot rolls sideways into pronation or supination, particularly if that sideways motion is extreme **[FIGURES 56 & 57]**. Otherwise, an unstable rocking chair effect is unnaturally created in sideways motion.

Also, it is optimal for the sole of a natural shoe sole to be **fully rounded** directly underneath the rounded sole of the wearer's foot, instead of flat, particularly fully rounded under the wearer's rounded heel, so that the shoe sole flattens the same way the foot sole flattens, particularly in the rounded heel area, as illustrated in the adjoining patent drawing.[23]

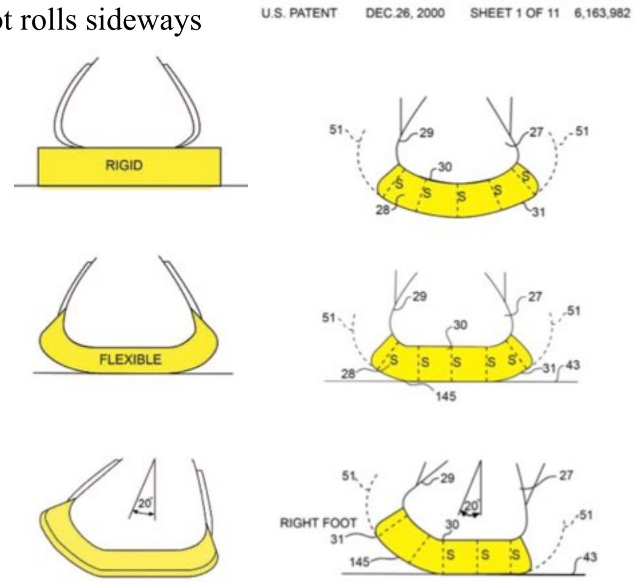


FIG. 56 FIG. 57

Finally, the natural shoe sole must have **uniform thickness** in frontal plane cross-sections directly underneath the wide dynamic footprint. If the shoe sole is uniformly thick only under the conventional static footprint, as is conventional, during extreme pronation or supination the wearer's foot will roll unstably down the tapered sole side with reduced thickness.

You can review the more detailed design principles in my issued patents at my website, **www.AnatomicResearch.com**. (I apologize in advance for the sometimes difficult readability of the patents, which is mostly inherent in utility patents, which are, first and foremost, technical legal documents.)

PUTTING THEORY INTO PRACTICE: A NEW PROTOTYPE BASED ON THE BAREFOOT

Translating this basic design concept into my **actual working prototype in 1993** resulted in a heel cross-section, which shows the outsole (black) and midsole (white) wrapped around a rounded inner surface that is flesh-colored to represent the wearer's heel (the prototype also had an insole paralleling the inner surface of the midsole but is not shown here) **[FIGURE 58]**.

Next to my **'93 prototype** is a rounded conventional shoe sole that is similar to the prototype, but is generally as unstable as other conventional shoes. **[FIGURE 59]** That is because only its outsole (off-white) wraps around the wearer's foot, but the midsole (black) is conventionally narrow and therefore does not mirror the barefoot sole, so the foot is encouraged to roll unstably downward to the outside during sideways motion from an upright position.

For stark comparison, the last heel cross-section is a typical rigid conventional shoe sole example (incorporating a popular gas cushioning system), which shows an upper surface rounded like the unloaded heel, but an effectively flat bottom sole (hollowed out). **[FIGURE 60]**

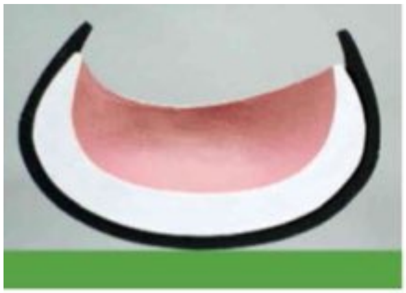


FIG. 58

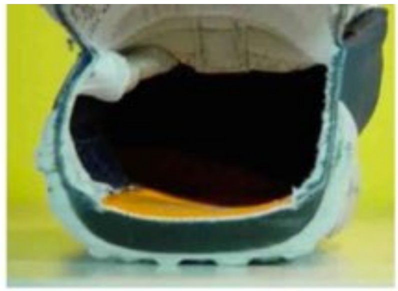


FIG. 59

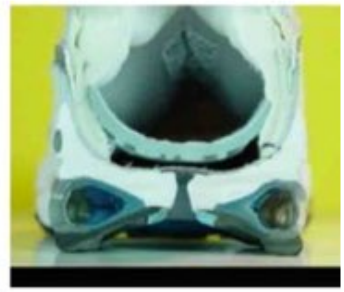


FIG. 60

The two sharply contrasting conventional approaches in shoe sole structure are shown at the most basic possible level in the examples of the classic Adidas **Adilette** slide and the Under Armour **Fat Tire** sandal (and shoe, not shown). The **Adilette**, **FIGURE 60A**, shows in cross-section a rounded, foot sole conforming upper surface and a flat lower surface. The **Fat Tire**, **FIGURE 60B**, shows in cross-section the polar opposite: an almost flat upper surface and a rounded lower surface.

In common, both are too narrow and functionally rigid. Neither is stable, but in entirely different ways. The **Adilette** holds the wearer's foot in an upright position, resisting supination or pronation, whereas the **Fat Tire** not only provides no resistance to supination or pronation, but actually exaggerates sideways motion. When tilted in extreme supination, the **Adilette** teeter/totters on a sharp edge, before powering over out of control, while the **Fat Tire** rolls continuously downhill, ever more forcefully.

FIGURE 60C is a relatively new, all plastic version of the leather, cork, and rubber classic version of the Birkenstock **Arizona** sandal, shown in a cross-section similar to the **Adilette**, but with the upper surface conforming to a flattened load-bearing wearer's foot.

Although the popular **Adilette** and **Arizona** models of FIGURES 60A & 60C have an upper sole surface curvature similar to my prototype of FIGURE 58, their flat lower sole surface indicates a design fresh from the **Flat Earth Society**, where designers still blindly believe the shoe sole is an extension of the flat earth instead of an extension of the wearer's rounded foot sole.

FIG. 60A

FIG. 60B

FIG. 60C

AN EXPANSION OF THE LEAP & LAND ANKLE SPRAINING SIMULATION TEST

What kind of performance difference can be achieved by making these relatively straight-forward theoretical sole design corrections in the new and different **'93 prototype** compared to the barefoot and to the basic design of conventional shoe soles?

Beginning with the same revolutionary test first conducted in 1993, which was the leaping and landing in the common lateral ankle spraining position **[FIGURE 22]**, a new test comparison was made to illustrate the extreme stability performance difference that exists between bare feet versus conventional shoe soles. Added to the test were the 1993 prototype, as well as a newer prototype developed in 2005 with several design modifications.

The 1993 prototype abbreviated the enlarged rounded sides to independent bulges that were located only the essential bone structures of the foot, giving it a unique look **[FIGURE 61]**, whereas a later 2005 prototype has a more conventional look with rounded sides that surround the periphery of the prototype sole continuously and with a flat edge of the upper portion of the side to provide a much more conventional shoe sole look.

Fig. 61

In a **Leap & Land Ankle Sprain Simulation Test**, landings for the bare foot were routinely stable, without ankle pain, landing on a wide base of support under the lateral half of the bare foot sole. Landing on both bare feet in that position is easy (the white area is the wide ground contacting area of the bare foot, shown in an underneath view). **[FIGURES 62 & 63 & VIDEO LINKS]**

FIG. 62

FIG. 63

Of course, with conventional shoes, the same leaping test could not be undertaken without extreme danger of injury to the test subject. Therefore, only the static **Standing Ankle Sprain Simulation Test** was attempted. The test subject shown was able to balance for only a second on the knife edge (shown in white in an underneath view) of the inverted conventional shoe sole. Besides extreme unstability, the torsion created by the tilting sole caused pain in the subject's ankle joint. The same extreme instability was present even in a running shoe that has been advertised as having barefoot-like flexibility, which however actually lacks sufficient flexibility to flatten like a barefoot heel in the same position, as previously shown. **[FIGURES 64 and 65 & VIDEO LINKS]**

FIG. 64

Fig. 65

In marked contrast, when the much more difficult **<u>Leap & Land</u> Ankle Sprain Simulation Test** was conducted with the 1993 shoe prototype and with a 2005 initial stage sole-only prototype (in translucent plastic, with an ad hoc clear plastic shipping tape "upper"), both soles were stable when repeatedly landing in the lateral ankle spraining position, without ankle pain, as shown in rear and perspective views. **[FIGURES 66-68 & VIDEO LINKS]**

FIG. 66

FIG. 67

FIG. 68

The same **<u>Leap & Land</u> Ankle Sprain Simulation Test** is shown here in underneath views of landings in a 1997 Adidas **Key Trainer** athletic shoe similar to **my 1993 shoe prototype** and the **2005 sole-only prototype** (the same sole as above, but in yellow plastic instead of translucent). The view on the right is included to illustrate how the focus of structural support can shift forward for balance in both prototype and barefoot conditions shown side by side. **[FIGURES 69-71 & VIDEO LINKS]**

FIG. 69

FIG.70

FIG. 71

As shown in the adjoining pressure-sensor footprint while standing in the maximum supination or lateral **Ankle Sprain Simulation Test** position, the greatest point pressures are not located at the heel, where pressure is spread evenly in a large area, but rather at the base of the fifth metatarsal bone and at the head of the fifth metatarsal bone, at which point peak pressure occurs. **[FIGURE 72]**

TRIGGERING AN EVEN MORE EXTREME LEAP & LAND ANKLE SPRAIN SIMULATION TEST

After the preceding series of **Leap & Land Ankle Sprain Simulation Tests** was conducted, which was planned as sort of a warm-up for the main event, I decided to precede with a much more radical test, one never before undertaken. I decided to use the most classic ankle spraining trigger during the landing from the jump. That is, the same classic trigger that forces extreme ankle pain or sprain in a conventional shoe every time. The trigger used to initiate the sprain simulation test was to land the test foot on the side of a shod foot, which automatically forces the test foot to invert uncontrollably. This real-world obstacle-triggered **Leap & Land Ankle Sprain Simulation Test** had never before been attempted!

That is because with a conventional shoe, even a high-performance athletic shoe, it constitutes a form of unavoidable ankle suicide. Since a foot-triggered **L&LASS Test** is dangerous to conduct in a conventional shoe sole, the test subject was provided with a safety line with which to support himself as necessary in order to avoid excessive ankle pain or injury.

As expected, the conventional shoe was uncontrollably unstable during landing, forcing the test subject to support his entire body weight with the safety line, as seen in front and underneath views below **[FIGURES 73 & 74 & VIDEO LINKS]**.

Fig. 73

Fig. 74

In contrast, both the bare foot and the 2005 prototype slide off the sprain-triggering shod foot into a stable position of support on the ground, so that the test subject could support his full body weight on the single inverted test foot without ankle pain, as seen in front and underneath views below. **[SEE FIGURES 75-77 & VIDEO LINKS]**

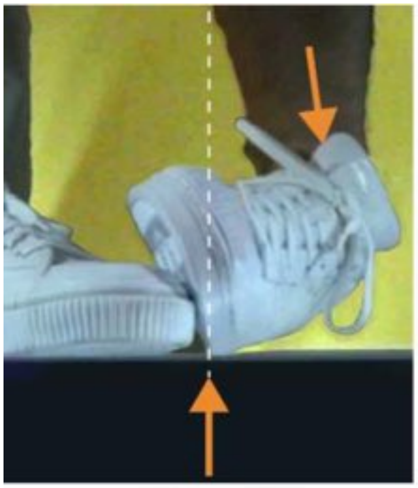


Fig. 75

Fig. 76

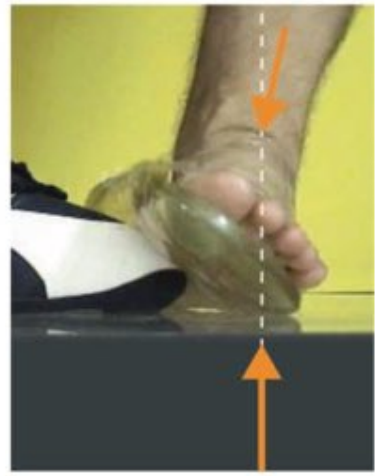


Fig. 77

It cannot be emphasized enough that no conventional shoe by itself can pass this realistic ankle spraining test. For that matter, it is impossible for any of them to pass even the far easier standing ankle sprain simulation test. And yet, it would be easy to fix them with simple design changes that are well within the capability of any athletic shoe company to implement, certainly the largest ones, Nike and Adidas. If I can do it many times with so few resources compared to them, as shown in these real-world condition tests, so can they with their many decades of design and manufacturing experience developed during the production of hundreds of millions of athletic and other shoes.

A DESIGN FOR CLASSIC FOOTWEAR SOLE CORRECTED: LOOKS CONVENTIONAL, BUT WITH MUCH BETTER STABILITY AND COMFORT

One obvious potential obstacle to the widespread adoption of new, naturally stable shoe soles is whether they can be made to look like the conventional shoe that consumers expect, instead of some rather unusual new design, like my ***'93 AR Prototype*** and the similar Adidas' **Key Trainer** **[FIGURES 4A-E and 5A-E]**. Moreover, footwear companies do an enormously profitable business in classic models and designs (which have no expensive design, development, or production costs), so generally most footwear commercial products need to look relatively conventional in appearance in order to look like what consumers already have been proven that they expect.

The athletic footwear made by Adidas under our 1994 patent license would likely be judged by most as substantially unconventional in appearance for that time period, although some were very popular, like the ***Crazy 8*** basketball shoe. However, in contrast to those relatively unique designs, it is possible to make far more stable footwear that outwardly appears to have classically conventional soles with flat, vertical sides. To prove this, in 2000 I undertook a design project with athletic shoe industry experts in biomechanics, design and manufacturing at **i-generator,** founded by Dr. Simon Luthi, former Adidas Director of Research, and others. I wanted to develop a footwear product that was eventually dubbed the "**IGAR**" slide (the name combining the initials of **i-g**enerator and **A**natomic **R**esearch, my company).

Prototyping a slide instead of a shoe was also undertaken specifically because it also made the entire structure of the novel slide sole easy to see and understand by any wearer. In contrast, the typical upper of a shoe would almost completely mask the rounded inner surface of the prototype sole, thereby necessarily hiding the unique structural concept from the wearer. I envisioned the slide sole as potentially having a special additional role as an education device.

THE IGAR SLIDE PROTOTYPE

The product of the collaboration is the **IGAR** prototype slide shown below on the left. For the **IGAR** project, the existing footwear product used as a baseline for the conventional footwear sole design was the Adidas **Adilette**, shown on the right, a slide/sandal that has been produced in volume continuously for decades since the 1970's and is still very popular today during the COVID-19 pandemic. When worn, the **Adilette's** outward appearance is totally conventional, with flat, vertical sole sides. The **Adilette's** simple one-material sole follows the standing outline of the wearer's foot sole and has flat, vertical sides with a flat, horizontal bottom. **[FIGURES 78A-78D & VIDEO LINK]**

FIG. 78A

The **Adilette** slide's single design departure from conventional footwear soles is its upper surface, which is shaped like the wearer's rounded unloaded foot sole. That design change was apparently made for comfort.

As far as I know, the closest other popular footwear product with a similarly contoured upper surface is the **Birkenstock** sandal, an even older design. However, the upper surface of the "**Birky**" is shaped to conform to the wearer's loaded foot sole, so it is flattened in areas of the foot sole that would be flattened under a standing bodyweight load, such as the heel, forefoot and toes.

FIG. 78B

Although a new feature when designed and still unconventional, the completely rounded upper surface of the **Adilette** is nevertheless hidden from view when the slide is worn, so the slide's outward appearance then is completely conventional. The **IGAR** slide's upper surface is roughly the same as that of the **Adilette**, contoured to the rounded shape of the unloaded wearer's foot sole.

FIG. 78C

FIG. 78D

The principal new feature unique to the **IGAR** slide is its lower surface, which parallels the rounded shape of the wearer's unloaded foot sole and therefore also parallels the rounded upper surface of the slide sole, as shown in the accompanying comparison photographs of the two slides. **[FIGURES 78E-78F & VIDEO LINKS]**

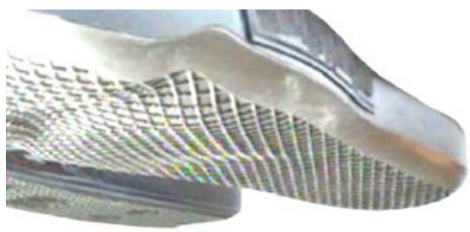


FIG. 78E

FIG. 78F

A CRITICAL SOLE DESIGN FEATURE OF THE IGAR SLIDE

A fundamental new design feature of the **IGAR** slide sole was that the thickness of the sole was the same on both sides as underneath, as measured in frontal plane cross-sections, so natural side-to-side stability was maintained, as shown in yellow in the heel and forefoot cross-sections below. This uniform thickness is a critical feature in allowing the slide sole to maintain the barefoot stability that occurs with the barefoot directly on the ground.

In contrast, comparing the **IGAR** and **Adilette** slides, heel and forefoot of both slides are shown in frontal plane cross-sections in **FIGURES 79A & 79B** (taken from original patent drawings, which explain the plethora of numbers). The **Adilette** slide sides (shown as cross-hatched increases in thickness added to the **IGAR** yellow sides) extend downward to create a conventional flat surface, instead of the rounded yellow sides of the **IGAR** slide alone.

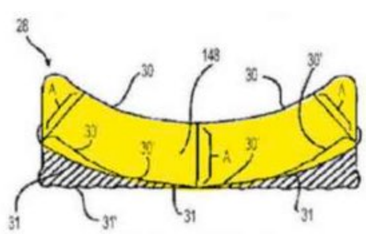


FIG. 79A

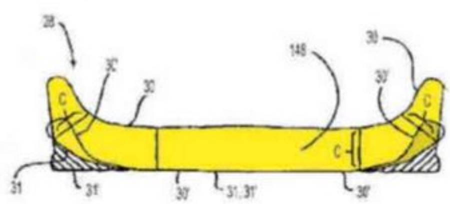


FIG. 79B

PERFORMANCE TESTING: THE LEAP & LAND ANKLE SPRAIN SIMULATION TEST

In performance testing, the conventional Adidas **Adilette** slide sole (on left) was grossly unstable in the extreme supination position of the **Standing Ankle Sprain Simulation Test**, as expected. **[FIGURE 80 & VIDEO LINK]**

The **IGAR** slide (on right) was far more stable, but its vertical sides made it less wide than the dynamic footprint, so it was not as stable as the later **2005 slide prototype** shown previously. The **IGAR**'s greater than expected lateral stability was due primarily to the stability provided in the forefoot, which was relatively good, as shown in the front view. **[FIGURE 81 & VIDEO LINK]**

FIG. 80

FIG. 81

The **IGAR** slide also performed well in the **Leap & Land Ankle Sprain Simulation Test**, landing with better lateral stability than expected **[FIGURE 82 & VIDEO LINK]**. It was even relatively successful in completing the actual sprain simulation test of jumping onto a shoe, although there was some observable heel slippage. **[FIGURE 83 & VIDEO LINK]**

FIG. 82

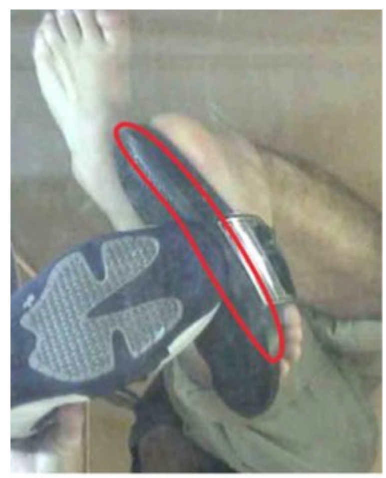


FIG. 83

BESIDES MUCH BETTER STABILITY, THE IGAR SLIDE ALSO EXCELS IN THE MOST IMPORTANT FEATURE OF FOOTWEAR: COMFORT

Besides the unexpectedly high degree of natural barefoot lateral stability provided by the **IGAR** slide, it also provides the additional barefoot benefit of much greater comfort. The increase in comfort was noticeable when standing, but was most apparent during locomotion, particularly when running. Its natural structure allowed it to interact neutrally with the ground like the barefoot sole, whether standing, walking, or running.

In comparison, running in classic **Birkenstocks** or Adidas **Adilettes** is highly impractical, due to extreme foot discomfort and instability. They are only okay for standing and walking. Ironically, the Adidas **Adilette** was reported by Adidas to be an exceptionally popular model in 1st Quarter 2020 during the Covid-19 pandemic, apparently due to its comfort when locked-down inhouse for month after month.

Even so, besides much better stability, the **IGAR** slide was distinctly more comfortable than the **Adilette**, because it is contoured to the natural shape of the unloaded foot, forming a flexible cradle for it. So, in an unprecedented way, the **IGAR** slide excels in the same feature, **comfort**, which is critical to both athletic and fashion shoe customers, according to a ***Footwear News*** article. **[FIGURE 84]**

In addition, by supporting the wearer's foot sole in its unloaded rounded condition, the **IGAR** sole acts in effect like an orthotic formed by the entire sole of the slide that deforms under a bodyweight load in parallel with the deformation of the foot sole. That functionality is impossible for a conventional, flat bottomed shoe sole.

THE PRE-PRODUCTION ARIG NATURAL BAREFOOT SOLE BASED ON THE 2005 SLIDE

In 2017, I undertook a new project with a similarly experienced team at **i-generator** to design and have manufactured actual preproduction samples of a new "**ARIG**" slide prototype developed from the 2005 slide prototype shown previously. It has a significantly wider sole than the ***IGAR slide*** prototype and is therefore sufficiently wide to support the dynamic foot throughout its full range of maximal pronation and supination motion. The ***ARIG slide*** name once again combined the initials of **i-g**enerator and **A**natomic **R**esearch, my company, but with the order reversed for this project to differentiate between the two.

As with the ***IGAR slide***, the ***ARIG*** prototype was based on a slide again because it has the unique benefit of making the entire structure of the novel slide sole in as simple a form as possible, with just a minimal single layer of material, not multiple layers of different materials.

Also, the minimal upper makes the unique sole easy to see and understand by the wearer. In contrast, the typical upper of a shoe would hide the substantially contoured inner surface of the sole, thereby unavoidably concealing the basic design concept underlying the sole structure. As with the ***IGAR slide***, I wanted the ***ARIG slide*** sole to have a special role as a teaching tool.

As shown in the following design patent drawings of heel (on left) **[FIGURES 85A & 85B]** and forefoot (on right) **[FIGURES 85C & 85D]** in rear and front views, respectively, as well as in cross-sections, the wider **ARIG** sole conforms to the rounded shape of a wearer's unloaded foot sole and maintains a uniform thickness in the sides compared to the underneath portion. The upper (shown in dashed lines) is a hypothetical shoe upper representative of any typical shoe upper.


FIG. 85A


FIG. 85B


FIG. 85C

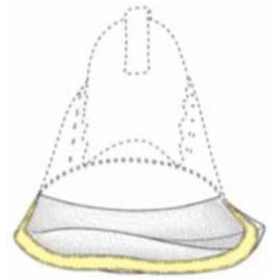


FIG. 85D

Shown also is a side view of the ***ARIG slide*** design patent sole in and a preproduction drawing in a cross-section taken at the centerline of the long axis of the ***ARIG slide*** sole. **[FIGURES 85E & 85F]** The shape of the slide sole conforms to the rounded shape of the unloaded foot sole of the intended wearer.

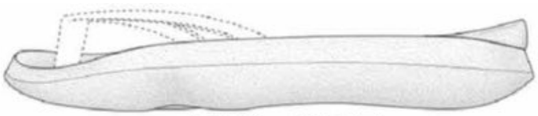


FIG. 85E

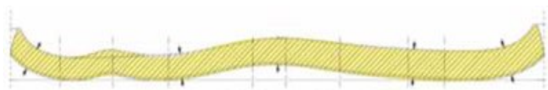


FIG. 85F

A side view of the ***ARIG slide*** sole in a design patent drawing with a hypothetical shoe upper is shown in **FIGURE 85G.** Photographs of perspective top and bottom views of the factory-produced preproduction (size 10) sample of the ***ARIG slide*** sole are shown in **FIGURES 85H & 85I.**


FIG. 85G


FIG. 85H


FIG. 85I

A photograph of a top view, a side view and a perspective view of factory-produced samples of the ***ARIG slide*** including a slide upper are shown in **FIGURES 85J, 85K & 85L.**


FIG. 85J


FIG. 85K

FIG. 85L


For testing purposes, a few ARIG slide samples were converted by a specialty shop into ***ARIG running shoe*** samples by stripping away the slide upper from its side attachments and cobbling in a fully-lasted running shoe upper (also with insole), as shown in **FIGURE 85M**.


FIG. 85M

It should be noted, of course, that this cobbled-together prototype is functionally limited, since it has the slide's combination midsole/outsole, not a rubber traction outsole and a more specialized cushioning midsole material like the common EVA (ethylene vinyl acetate) of a conventional athletic shoe sole.

Its sole also lacks designed-in flexibility that is necessary between the sole's heel and forefoot, since it is a designed as a slide sole, for which flexibility is less necessary because the wearer's heel is free to lift out from the slide's heel during the plantarflexion phase of walking or running.

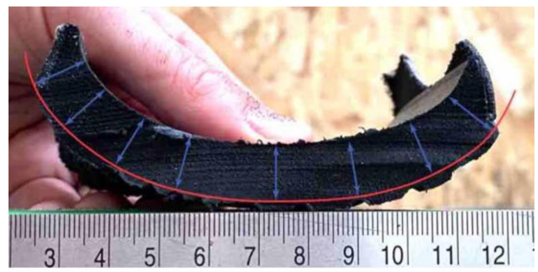


Fig. 85N

The uniform thickness of the ***ARIG Slide*** sole that provides barefoot-like stability was highly accurate, as seen in frontal plane cross-sections taken at the heel in **FIGURE 85N**. Other ***ARIG Slide*** sole frontal plane cross-sections taken at the midfoot (at the base of the 5th metatarsal bone) and forefoot (at the heads of the five metatarsal bones) showed the same frontal thickness thickness accuracy.[24]

Similar to FIGURE 85M, **FIGURES 85O & 85P** show examples of classic basketball shoes, the Converse ***All Star*** and the Adidas ***Superstar***, that have been modified in the simplest possible way by integrating the ***ARIG Slide*** sole structure into the conventional shoe upper of the ***All Star*** and ***Superstar***. The result indicates that the look of the classics is changed a little on the

Fig. 85O

Fig. 85P

sole sides, which go from vertical to tilted out at about 20°. The look is something like the old flared sides of running shoes that originated in the 1970's, but with a totally different internal sole structure. However, that change is not very noticeable except at ground level and from below the shoe sole. The structural change is almost invisible from above, as the shoes would typically be seen when standing or walking or playing in sports. The big change is functional – drastically improved stability like the barefoot.

FIGURES 85Q show an example of the classic ***Crocs Clog*** that also has been modified in the simplest possible way by integrating the ***ARIG Slide*** sole structure into the conventional shoe upper of the ***Crocs Clog***. Since the ***Crocs Clog*** is wider than the Converse ***All Star*** and the Adidas ***Superstar***, the ***ARIG Slide*** sole structure fits into the existing sole of the ***Crocs Clog*** so the sides remain vertical instead of tilted out 20°.

Moreover, the combination shown in these figures is the product of the simplest possible ***Photoshop***® merger of the classic shoe uppers and the new slide sole. A real merger by industry shoe designers for an actual production model would offer many different parameters – not just adding the classic tread design (omitted in FIGURES 85O & 85P) – to manipulate in various ways to make any such modified classic shoes look even more like the original classic. That can be accomplished while at the same time retaining the critical new elements of the slide sole structure that provides barefoot-like stability improvement.

THE ARIG SOLE DESIGN IS PROTECTED BY DESIGN PATENTS ONLY – THE GENERAL STABILITY DESIGN IS FREE TO USE

It is important to note a key intellectual property fact about the specific ***ARIG*** sole design described and shown above. Its novel design features are only protected by design patents, which cover the look of the design, but not its critical functional structure that provides natural stability. The utility patents covering functional structure that I originally developed in the late 1980's and 1990's and licensed to Adidas have all expired. Therefore, any footwear company can design and manufacture footwear now with similar sole structure as long as it does not look the same, so it can functionally perform the same. Putting it more simply, the basic barefoot stability sole design I pioneered years ago is now generic, open for anyone to use.

Moreover, the basic barefoot stability sole design is very general, so it has the potential for an infinite number of variations. Although the design example shown here is a simple slide, the basic stability sole design can be used to make any category of shoe, from performance athletic shoes to work shoes to street shoes to fashion footwear. It can even significantly improve the stability and comfort of spiked high heels (although I personally would hate to facilitate their continued use, that may be inescapable). Unlike the simple single material layer of the ***ARIG*** slide, the basic design can be made using any variation of conventional layers of outsole, midsole, heel lift, and insole or sockliner.

Some examples of the limitless potential design variations are shown in my U.S. utility patents (see www.AnatomicResearch.com). Many never used improvements to conventional shoe soles are available for further development and are also shown there. Most of the U.S. patents shown there have reached the end of their legal term and have expired, so anyone can copy any part of them for free.

Moreover, with regard to the many other footwear patents I own that are still well within their legal term, such as the computer-controlled smartsole inventions mentioned earlier, I plan to assign them to a new research foundation dedicated to research on the structure of footwear soles, because conventional shoe soles also have an elevated shoe heel problem that is far more serious medically than the accidental injuries caused by the stability problem described here. That problem is quite complex and has been the subject of another part of my footwear sole investigation that has been ongoing over many years and will be the principal research focus of the foundation. My patents in the research foundation will be available for free use by all footwear companies that financially support the foundation at a reasonable level relative to their resources. More about later, in my second book, ***Unnatural Deformity***, which is summarized at the end of this one.

ADDITIONAL TESTING AT THE MAYO CLINIC LAB AND AT BIOMECHANICA'S LAB

A fair number of ***ARIG*** slide preproduction samples have been received from the factory and have been distributed for wear testing by test subjects with a wide range of different ages and fitness levels. That wear testing is ongoing currently, but has been interrupted somewhat by the COVID-19 pandemic, like everything else.

In addition, I had the opportunity to test a nearly identical but earlier preproduction sample of the ***ARIG*** slide at the **Motion Analysis Laboratory** at the **Mayo Clinic** in Rochester, Minnesota, during a field trip at the 2018 annual conference of the **American Society of Biomechanics (ASB)**. The lead researcher of the lab, Dr. Kenton Kaufman, developed a treadmill capable of inducing postural perturbations together with a vest attached to an overhead harness for the safety of the test subject. The treadmill system is used to train the elderly to recover from sudden, random postural perturbations to avoid falls. **[FIGURE 86]**

His system was being demonstrated to the visitors from the **ASB** conference by allowing volunteers to be actually tested in the perturbation system. I volunteered wearing my pair of ***ARIG*** slides, as did several other **ASB** volunteers wearing conventional footwear (mostly athletic shoes). In this informal test, every suddenly "perturbed" **ASB** volunteer fell and had to be restrained by the safety harness, but not me. The ***ARIG*** slides allowed me to maintain my footing, as if my feet were bare, whereas defective design of conventional shoes soles made the other volunteers fall. (The treadmill system photo is from Mayo Clinic's **Wounded Warrior** prosthetic program.) [SEE VIDEO LINK]

What seems reasonable to conclude from this informal test was that the other test subjects wearing conventional shoes were forced by the sudden and powerful treadmill perturbation to roll off the outside edge of either the inner or outer side of their conventional soles, forcing the wearer to fall because of the lack of direct structural support (and, with their foot in an extreme supination position, possibly an instantaneous ankle pain-avoidance reflex). In contrast, in the ***ARIG*** slides, it was relatively easy for me to recover from test perturbations, maintaining barefoot-like stability to avoid a fall.

Several ***ARIG*** samples were provided for testing to a commercial biomechanics lab, **Biomechanica**, founded by Dr. Martyn Shorten, former Director of Research at Nike (their second).   His lab provided running shoe evaluations for ***Runners' World*** for over a decade or so. Staff at Biomechanica performed conventional running shoe tests that included footwear mechanical evaluation, plantar pressure distributions, and kinematic screening.

The overall evaluation in terms of a conventional running shoe comparison was that the biomechanical characteristics of the ***ARIG*** slide were typical of what is loosely called a "minimalist" running shoe in the footwear industry. In the loose industry definition, "minimalist" means the ***ARIG*** slides are lighter with thinner soles and less cushioning, and have little or no heel lift.

Of course, this testing was entirely conventional and did not in any way test the stability performance of the running shoe in extreme supination or pronation at any load, such as the **SASS Test**, much less running or jumping onto a single foot to simulate an ankle sprain under a significant multiple of body weight loads.

ANATOMIC RESEARCH IS DEVELOPING FOOTWEAR PROTOTYPES TO SERVE AS AS PROOFS OF CONCEPT

The ***ARIG*** slide prototype was developed to be the simplest possible structural model to serve as an important **proof of concept** that a footwear sole made with typical mass-production manufacturing technology can provide, for the first time, stability like that of the barefoot sole, plus much better comfort, even with just a single layer of sole material.

It completely lacks the usual footwear outsole and insole, or any other of the conventional bells and whistles of a modern athletic shoe. Even so, the ***ARIG*** slide prototype still provides the normal important attributes of a conventional shoe sole, such as cushioning, traction, and protection. I designed the ***ARIG*** slide sole to function as a basic education tool, since its entire structure is easy to see and understand, unlike a regular shoe with an upper and insole that conceal the upper surface of the sole.

I undertook the development of the ***ARIG*** slide prototype primarily as a public service effort with the goal of enabling the footwear industry to easily use the ***ARIG*** slide as a general stability model for development of its own stable footwear products. The basic structural design of the model sole of the ***ARIG*** slide is not encumbered with any utility patents that could be used to prevent copying and/or modifying any of its key structural features.

Instead, the design of the ***ARIG*** slide is protected only by design patents. Design patents just prevent copying the precise ornamental look of the slide, not its critical functional structure, which would be a utility patent issue if they had not expired, which they have. Moreover, like anything else, the ***ARIG*** slide example itself is the product of many design tradeoffs and is not perfect and can potentially be improved in any number of ways, in structure, function, and aesthetics, which would further ensure its free use by any footwear company using it to develop its own new footwear sole designs.

As a public service, to further expedite the fastest possible adoption of safe and stable footwear, I will make the initial factory production of the ***ARIG*** slides readily available to footwear companies for their use as a general structural model for testing and evaluation to assist their efforts to correct the inherently faulty design of their conventional footwear soles.

In addition, as a limited scale research and development study, and a public service to expedite rapid adoption, I plan to sell a limited number of ***ARIG*** slides in at least several select sizes to consumers for experimental performance and wear testing, including testing for injuries. I also plan to use as the ***ARIG*** slides as both footwear industry and public education devices to physically demonstrate to wearers the drastic increase in stability and comfort that is now possible in a simple, non-defective, barefoot-like footwear sole design, in contrast to conventional footwear soles.

I plan to develop other athletic shoe designs at Anatomic Research also to demonstrate them as proof of concept for basic categories of footwear and again for both footwear industry and public education. Currently under development are basketball, running, and other athletic and casual shoe designs based on barefoot-like footwear sole structures similar to the ***ARIG*** slide sole.

In addition, prototypes are also being developed by Anatomic Research for common types of conventional shoe soles that include simple modifications that significantly improve their stability, as will be discussed later in regard to **FIGURES 88-91**. The goal is to make conventional footwear soles measurably safer as rapidly as possible with relatively easy interim improvements, even though the resulting soles are significantly less stable than a barefoot-based footwear sole like the ***ARIG*** slide sole.

Such halfway designs may be very useful as the footwear industry rapidly transitions over a few years to much safer footwear from its current defective products. The overall goal is to develop a practical way to make the most overall safety improvement possible in the shortest possible time, moving first from bad stability to better stability, then from better to the best possible stability like that of the barefoot.

TARGETING THE UNMET NEED OF THE ELDERLY WHO SUFFER THE MOST FROM FALLS

The total economic cost of 3 million annual accidental falls by the rapidly growing elderly population (now including Baby Boomers) for their Emergency Department visits, hospitalizations, and deaths is estimated by the **CDC** to be $67 billion annually in 2020, and does not include their substantially reduced quality of life or the shortened span of that life.[3] The costs in the near future will be substantially worse, given that data from the Centers for Medicare and Medicaid Services indicates that the U.S. population above age 65 is estimated to be 68 million in 2028, up 10 million or close to 20% in just seven years.

It is typical for the elderly to spend most of their time indoors where they typically go barefoot, wear socks without shoes, or wear slippers. The available evidence from studies indicates that doing so puts them at increased risk for falls, traction on artificial surfaces being a particular problem.[24A] The only other option is wearing shoes, which are defectively unstable.

Filling the special need of the elderly (and disabled with compromised ambulatory capability) for a safe level of stability has never been a major goal of the footwear industry. Significant improvements would have been impossible anyway because of the severe limitations of conventional sole designs.

The only stable existing alternatives are super-minimalist footwear without the cushioning midsole that is critical to protect tender elderly feet. Notable examples include: Vibram ***Five Fingers***® running shoes, which are unusually difficult to put on; ***Skinners***®, which are very nice socks with embedded rubber traction outsoles; and ***FitKicks®***, which are elastic fabric slippers with very thin soles (which are a little too narrow). The first two examples would not work well in the shower or bath, where the barefoot elderly are at exceptional risk of slip and fall accidents, and need an easy-to-use stable alternative. They need footwear with good traction that is easy to put on, easy to keep on, and easy to take off.

There are other super minimalist footwear variations similar to the Five Fingers, including those with a conventional uni-toe forefoot like Terra Plana ***Vivo Barefoot*** shoes, but all of them seem too narrow with a conventional indentation of the lateral midfoot portion of the shoe sole (shown in **FIGURES 49 and 88**). As a result, in extreme supination they are less stable than the barefoot (although much better than conventional shoe soles that are much thicker) and not designed for easy use in the shower or bath, even though they have some models specifically designed for aquatic use.

A personal goal of mine is to try to help show the way for the industry to meet that special unmet need of the elderly. Fortunately, the ***ARIG*** slide constitutes a successful proof of concept prototype sole that serves as a general model with an exceptional capability that well serves the special stability and comfort needs of the elderly.

For example, the slide is easy for the elderly to put on and take off without any use of the hands. It can be put on easily like a loafer. But once on, it stays on, whether the senior is sitting, standing, or walking. The enveloping sides of the slide's contoured sole securely position the senior's foot, holding it in place within the slide.

The bare human foot unfortunately slips easily on modern artificial surfaces. The sole of the ***ARIG*** slide has an outer surface with a traction tread pattern to prevent slips, such as on the tiled surfaces in the otherwise dangerous bathroom. The slide can potentially even be worn in the shower, although the current initial version is less than perfect for doing so, since it lacks a rubber outsole, which would provide the best traction in wet conditions like the bathroom.

Most of all, of course, designs like the ***ARIG*** slide are uniquely stable, unlike fall-prone conventional slides and bedroom slippers, and are much more comfortable too. They would be very inexpensive to manufacture and sell in volume, and could be a tremendous value to the elderly.

THE NOW OBVIOUS INHERENT INSTABILITY OF CONVENTIONAL SHOE SOLES HAS CREATED HUGE COSTS TO SOCIETY AND MUST BE CORRECTED BY THE FOOTWEAR INDUSTRY

Ankle sprains have been widely recognized for many years as the most common athletic injury in the U.S. and the most common reason for hospital Emergency Room visits. Obviously, the same inherent instability of conventional shoe soles that directly causes ankle sprains probably also directly causes falls. Both frequently occur together, with an ankle sprain often causing a fall, but due to the artificial sole instability alone, falls occur independent of ankle sprains.

However, I was astounded to learn when I delved more deeply into U.S. public health care statistics that the footwear instability defect is far more serious than anyone would expect, because of its obvious direct connection to accidental falls. What I found in health statistics from the U.S. **Centers for Disease Control and Prevention (CDC)** is quite astonishing: if only half of those falls were due to the shoe sole stability defect, a very reasonable estimate in the absence of more accurate data, it would be the direct cause of an estimated 3,200,000 hospital Emergency Room visits, 700,000 hospitalizations, and 20,000 deaths every year.[3]

Ignoring the death toll, the estimated medical and work loss economic costs alone of those accidental falls each year is about $77 billion. To put this in the proper perspective, those avoidable costs are more than the estimated current total annual footwear sales of the athletic footwear industry of about $70 billion.[4]

That specific estimate of the damage and associated costs caused by the shoe sole defect is unfortunately only my conservative best guess. The worst case estimate of the damage is closer to twice as high and a logically reasonable analysis suggests that it is more likely to be correct, as you shall soon see. Even the lowest conceivable damage estimate is roughly a 9/11 event every year in terms of deaths and economic cost.

Therefore, it is shocking news that the consumer cost of shoes sold in the U.S. is exceeded – possibly far exceeded – by the economic cost of the damage caused by the instability of those shoes, all the more so because that shocking situation has been true for untold generations, despite only now becoming evident.

The following explanation of this avoidable health catastrophe is based directly on website-published **CDC** statistical data and I believe is therefore sufficiently compelling that it requires immediate action now by the footwear industry to end the ongoing major medical emergency as quickly as possible.

A MAJOR MEDICAL PROBLEM, ANKLE SPRAINS ARE ARTIFICIALLY CAUSED BY DEFECTIVE SHOE SOLES

The conventional medical and anatomical understanding of the modern human ankle is that the ankle is inherently unstable, as indicated by this medical textbook titled "**THE UNSTABLE ANKLE**." **[FIGURE 87A]**

Instead, based on the evidence presented in this book, the correct scientific understanding is that it is the design of the conventional shoe sole that is inherently unstable, not the ankle. **[FIGURE 87B]** The unstable ankle is an effect that is directly caused by the defectively unstable structural design of conventional shoe soles.

This conventional misunderstanding has had a major medical impact with direct medical and work loss economic costs, as well as a significant cost in terms of a lower quality of life. That is the ugly reality. Only about half of ankle sprains are treated medically, but those that do total over 23,000 per day and about 10 million a year in the U. S. in emergency room and orthopedic office visits.[25] They are the most common reason for hospital emergency room visits. A U.S. Army study indicates that 10% of active-duty Army personal experience ankle sprains every year. Over 25% of insured patients with ankle sprains have been given opioid prescriptions, potentially adding to the opioid crisis. Without proper and timely treatment (as is the case for the half that are not treated medically), 15 percent to 40 percent of these ankle sprains become chronic injuries with greater instability and risk of repeat sprains, as well as continued pain and swelling.

About 1% of ankle sprain patients each year, totaling about 100,000 patients, remain disabled for life. Chronic ankle instability increases the risk of developing serious bilateral asymmetry throughout the body and is associated with reduced hip strength and altered knee mechanics, which are closely associated with osteoarthritis and the prevalence of hip and knee replacements.

Only about half of ankle sprains are treated medically according to the **CDC.** As a personal example, I badly sprained my right ankle at age eleven at a roller-skating party, but was not treated medically since it was presumed to be only a bad sprain. Not until I began to observe some bilateral structural problems as a fairly serious runner over a decade later did it become obvious (albeit only with rather obsessive investigative rigor on my part) that I actually had broken my ankle decades earlier, not sprained it.

In retrospect, the break was obvious. The tip of my right fibula healed in a misaligned position that clearly did not match my normal left ankle. The subtle deformity abnormally limits the range of motion of my right ankle during locomotion, causing bilateral asymmetry problems, especially during running.

MOST SLIP AND FALL INJURIES ARE CAUSED BY THE SHOE SOLE INSTABILITY DEFECT

Falls are the most common cause of sports and recreation injuries according to the **CDC**, over 65% greater than the next highest cause, and sprains, strains, and fractures make up 61% of those injuries, although which is cause and which is effect may be uncertain or even reversed.

Conversely, it should be recognized that, with virtually no exceptions, ankle sprains always cause falls, due to the intense ankle pain. Trying to avoid or mitigate the first very intense pain from the onset of a twisted ankle also results in a fall even if a sprain is avoided. The instinctive immediate reaction to the intense pain at the onset of a twisted ankle is an instantaneous attempt at pain relief by lifting the affected foot, thereby directly causing an uncontrolled fall to avoid more serious damage to the ankle. The fall reaction is typically observed even in superstar athletes.

Almost all animals with legs are quadrupedal. Only a tiny few are bipedal. Among the bipedal, humans are the most recent converts and therefore the least highly evolved at performing that highly unique form of locomotion, which is inherently less stable than quadrupedal locomotion.

During bipedal locomotion, humans must provide active control of balance from side to side in the frontal (or coronal) plane, since bodyweight load is constantly shifting back and forth from left foot to right foot. It is therefore well known in biomechanics that the human body is unstable from side to side in the frontal plane during locomotion,[26] as illustrated in **FIGURE 87C**.

In a conventional shoe sole it is therefore important to understand that accidental slips on ice, water, gravel, or other slippery or irregular surfaces almost always involve uncontrolled <u>sideways</u> motion of the foot on the ground. If the involuntary sideways motion is a significant part of the overall slipping motion, as it frequently is, it unavoidably causes the foot and ankle to excessively supinate or pronate. That excessive foot motion unavoidably tilts the conventional shoe sole and necessarily creates the same unnatural lateral ankle instability as previously shown in **FIGURE 16**.

Therefore, any naturally occurring slip becomes uncontrollable due to the stability defect of conventional shoe soles and therefore makes uncontrollable falls inevitable, with resulting injury, often serious, like hip fractures and traumatic brain injury. More than 95% of hip fractures are caused by falling, most typically by falling sideways.[26A] Accidental falls cause about half of all hospitalizations due to traumatic brain injury (TBI), about twice as often as the next leading cause of TBI-related hospitalization. Falls are the most common cause of TBI-related hospitalization for children. Falls are a leading cause of TBI-related deaths, second by only a small margin to suicide.

The sudden uncontrollable sideways or lateral instability makes attempts at instantaneous recovery from the slip difficult or impossible. This would seem to explain why most of 300,000 elderly hip fractures each year occur from falling sideways, which unfortunately focuses impact forces directly onto the hip joint. Three-quarters of the elderly hip fractures happen to females.

The medical and financial consequences of these accidental slips can be quite significant. For example, by chance I personally know an adult woman who is pre-Medicare and whose simple slip on some gravel on a paved road going down a gentle hill while wearing conventional athletic shoes resulted in a catastrophic ankle break. The complex fracture was so extensive she was told by her doctors that she would likely never walk again.

FIGURE 87D is the x-ray of her extraordinarily complex ankle reconstruction. Despite her extremely dire initial diagnosis, but only after an arduous year in a wheel chair with innumerable punishing rehabilitation sessions, she is now starting to walk again, albeit with significant difficulty and while also facing a mountain of medical and rehab bills.

SPORTS SUPERSTARS ARE ALSO VICTIMS OF SLIP AND FALL INJURIES

Tennis superstar Serena Williams and basketball superstar Paige Bueckers both experienced slips that resulted in serious knee injuries that interrupted their careers, as described earlier relative to FIGURES 13E-F and FIGURE 13G. Paige's slip is particularly interesting in that it occurred when her foot slipped forward, not to the side, but it still resulted in her conventional shoe tilting outward substantially coincident to her knee injury. This makes clear that even a forward slip in a conventional shoe sole results in unstable tilting because the associated leg itself is almost always tilted, not upright, whether running straight ahead or making an abrupt cut in sports, as Paige was attempting.

It is also clear in both cases, as well as previous and subsequent case described here, that the serious knee, ankle, or other injury can and usually does occur whether or not the slip and resultant footwear instability results in a complete fall onto the ground (which can result in ground contract injuries like traumatic brain injuries or hip fractures). Rather, the contact-free injuries appear to occur due to the unstable tilt of a conventional shoe sole causing an abnormal misalignment of ankle, knee, and/or hip joint when the associated leg is under high bodyweight load.

Alex Smith's story is a similar example to that of FIGURE 87D. Although it did not involve the ankle joint, it was actually a good deal worse. When being tackled in a game in 2018, the NFL All-Pro star quarterback for the Washington Football Team suffered an open fracture of his lower leg, both tibia and fibula bones broken, when his foot was forced to roll over well past an extreme supination position while wearing football cleats with rigid, narrow cleat-plate sole. The sole provided no structural support in the midfoot area proximate to the base of the fifth metatarsal bone. [see composite **FIGURES 87E-87H & VIDEO LINK**]

Alex's injury went from horrific season-ending to terrifyingly life-threatening in a few short days when he developed a severe infection of flesh-eating bacteria. Despite extensive treatment with massive doses of the best antibiotics, his life hung in the balance for several days, with amputation the only apparent option for his dangerously mutilated lower leg. (To spare the reader from inadvertently viewing disturbingly graphic images of his injured leg, I have included them elsewhere, in an Endnote, so you can choose to view them only if you wish.)[27]

Although there was very extensive permanent loss of muscle and associated tissue, he elected to keep the leg and try to rehabilitate it. After 17 operations and several years of extensive physical rehabilitation, Alex managed to recover sufficiently – against all odds – to author what has been called the greatest comeback in NFL history in 2020, able to again function as a winning NFL quarterback. His story is deeply moving and inspiring, and can be seen in an ESPN feature, "***Project 11: Alex Smith's Final Drive***."

I obtained a pair of what are the current version of the same football cleats that Alex was wearing when he was injured, as shown in the ESPN video in **FIGURE 87I**. It is the Nike ***Alpha Menace Pro 2 Mid***, which has the same sole and a refreshed upper design, as shown in **FIGURES 87J & 87K.** The cleats have a rigid, narrow cleat-plate sole with no direct structural support between the base of the 5^{th} metatarsal and the ground.

I subjected those cleats to informal SASS testing on dry natural grass like the grass shown in the ESPN video, which was dry (as indicated by the players appearing to have nearly clean uniforms in the second half of the game, when the injury occurred).

What I found was that the lateral stability of the cleats was extraordinarily bad in the maximally supinated position in which Alex's leg was fractured. The new, current model has an additional strap, presumably to improve stability, but I found that it had no apparent effect in my lateral stability test.

I also obtained and tested in the same way the other two models of football cleats that were available on the Nike website, the ***Vapor Edge Shark*** and the ***Vapor Edge Pro 360***. Both were just as laterally unstable and for the same structural reason.

With considerable irony, the only existing fix for the gross lateral instability created by this critical lack of midfoot structural support is to use the space opened up by the oversight to cover over it with a band-aid in the form of heavy ankle taping, as seen in **FIGURE 87L**, which is at least better than nothing

If anything, baseball cleats are even more unstable, as the following prime example indicates. The example is Kyle Schwarber, the National League Player of the Month for June, 2021, who was then the hottest hitter in major league baseball, with 16 home runs in 18 games. As shown in **FIGURES 87M & 87N & VIDEO LINK]**, in two consecutive strides, his left forefoot appears to be pronated almost completely off the top surface of the Nike cleat's forefoot. It is hard to imagine greater footwear instability.

Also, the exemplary baseball cleat's lower sole surface lacks any direct midfoot support for the main longitudinal arch or the base of the 5^{th} metatarsal bone, like typical football cleats. **[FIGURE 87O]**

The result for Schwarber was a pulled hamstring muscle. Note that, first, his left leg is hyperadducted (bent in) from his body's centerline, while, second, in his next running stride his right leg is abducted (bent out) from his body's centerline. **[FIGURE 87P & 87Q & VIDEO LINK]**

This appears to be a common sequence in hamstring injuries that occur when running. Another example, James Harden experienced a serious hamstring pull during the 2021 NBA playoffs after experiencing the similar extreme change sequence of leg abduction and hyperadduction in the same leg with extreme pronation. **[FIGURE 87R & 87S & VIDEO LINK]**

Although these examples are only suggestive, both appear to indicate that hamstring pull injuries occur in the presence of an abrupt change of sideways direction and accompanying leg hyperadduction with extreme foot pronation – pronation, again, being one of the avoidable stability flaws of conventional shoe soles.

Although the typical configuration of cleats for soccer shoes is a little different than American football shoes and also different than baseball shoes, they suffer from the same lateral instability with the same basic structural deficiencies.

THE MEDICAL IMPACT AND ECONOMIC COSTS OF FALL INJURIES AND DEATHS EACH YEAR ARE ENORMOUS

Although accidental falls include falls leading to ankle sprains and breaks, they also include other, non-ankle sprain falls that lead to many other injuries, such as sprains, fractures, and breaks of the foot, knee, hip, lower back, vertebrae, and arm, as well as head trauma injuries, many of which are quite serious. Again, ironically, many of those non-sprain falls occur while wearing conventional shoe soles since the wearer may intentionally fall to relieve intense pain from a twisted ankle. An instantaneous ankle pain-avoidance reflex in natural reaction to the severe pain of a twisted ankle causes the involved foot to be quickly raised by the conventional shoe wearer, causing an immediate loss of stability that results in an accidental fall.

According to statistics from the Centers for Disease Control and Prevention **(CDC)**[3], **Unintentional Falls (in red) are the leading cause of nonfatal injuries treated in Emergency Department visits in the U. S. in almost every age group**, excepting only ages 10-14 (barely) and 15-24, for a total of **8,591,683 accidental fall injuries that resulted in ED visits in 2017** (the latest year available). **[FIGURE 87T]**

That total for fall injuries was an extraordinary 233% greater than the next leading cause of Emergency Department visits. The associated annual costs for all fall-related emergency department visits include $55.1 billion in medical costs and $14.6 billion in work loss costs, totaling an overall combined annual economic cost of $69.7 billion in 2019, to which is added an estimated loss of $649.3 billion in quality of life.

FIG. 87T

National Estimates of the 10 Leading Causes of Nonfatal Injuries Treated in Hospital Emergency Departments, United States – 2017

Rank	<1	1-4	5-9	10-14	15-24	25-34	35-44	45-54	55-64	65+	Total
1	Unintentional Fall 120,007	Unintentional Fall 699,107	Unintentional Fall 530,390	Unintentional Struck By/Against 451,267	Unintentional Struck By/Against 755,114	Unintentional Fall 647,408	Unintentional Fall 623,997	Unintentional Fall 828,731	Unintentional Fall 1,047,959	Unintentional Fall 2,970,720	Unintentional Fall 8,591,683
2	Unintentional Struck By/Against 23,356	Unintentional Struck By/Against 254,793	Unintentional Struck By/Against 323,525	Unintentional Fall 451,183	Unintentional Fall 671,408	Unintentional MV-Occupant 579,446	Unintentional Other Specified 436,726	Unintentional Other Specified 473,983	Unintentional Other Specified 356,187	Unintentional Struck By/Against 312,954	Unintentional Struck By/Against 3,685,012
3	Unintentional Other Bite/Sting 13,505	Unintentional Other Bite/Sting 139,941	Unintentional Other Bite/Sting 107,577	Unintentional Overexertion 222,433	Unintentional MV-Occupant 595,092	Unintentional Struck By/Against 528,104	Unintentional Struck By/Against 396,695	Unintentional Overexertion 362,246	Unintentional Struck By/Against 278,211	Unintentional Overexertion 227,817	Unintentional Overexertion 2,569,850
4	Unintentional Other Specified 9,737	Unintentional Foreign Body 121,422	Unintentional Cut/Pierce 88,488	Unintentional Cut/Pierce 99,249	Unintentional Overexertion 493,072	Unintentional Other Specified 517,628	Unintentional Overexertion 395,791	Unintentional Struck By/Against 360,767	Unintentional Overexertion 258,488	Unintentional MV-Occupant 215,666	Unintentional MV-Occupant 2,500,353
5	Unintentional Foreign Body 8,618	Unintentional Cut/Pierce 60,421	Unintentional Overexertion 65,413	Unintentional Unknown/ Unspecified 67,107	Unintentional Cut/Pierce 345,982	Unintentional Overexertion 482,430	Unintentional MV-Occupant 381,110	Unintentional Poisoning 337,444	Unintentional MV-Occupant 249,192	Unintentional Cut/Pierce 162,819	Unintentional Other Specified 2,365,891
6	Unintentional Inhalation/ Suffocation 8,518	Unintentional Overexertion 58,727	Unintentional MV-Occupant 53,791	Unintentional MV-Occupant 64,349	Unintentional Other Specified 331,389	Unintentional Poisoning 401,819	Unintentional Poisoning 321,267	Unintentional MV-Occupant 331,388	Unintentional Poisoning 245,289	Unintentional Other Specified 143,563	Unintentional Cut/Pierce 1,823,358
7	Unintentional Fire/Burn 7,567	Unintentional Other Specified 47,348	Unintentional Foreign Body 52,756	Unintentional Other Bite/ Sting 57,014	Other Assault* Struck By/Against 312,205	Unintentional Cut/Pierce 372,787	Unintentional Cut/Pierce 269,865	Unintentional Cut/Pierce 235,597	Unintentional Cut/Pierce 184,284	Unintentional Poisoning 137,849	Unintentional Poisoning 1,755,044
8	Unintentional Unknown/ Unspecified 4,618	Unintentional Fire/Burn 41,066	Unintentional Pedal Cyclist 39,388	Other Assault* Struck By/Against 54,366	Unintentional Poisoning 246,611	Other Assault* Struck By/Against 355,927	Other Assault* Struck By/Against 212,483	Other Assault* Struck By/Against 171,022	Unintentional Other Bite/Sting 115,933	Unintentional Other Bite/Sting 116,191	Other Assault* Struck By/Against 1,261,580
9	Unintentional Cut/Pierce 3,844	Unintentional Unknown/ Unspecified 38,207	Unintentional Dog Bite 33,586	Unintentional Pedal Cyclist 49,283	Unintentional Other Bite/Sting 147,861	Unintentional Other Bite/Sting 176,855	Unintentional Other Bite/Sting 131,323	Unintentional Other Bite/Sting 135,907	Other Assault* Struck By/Against 95,550	Unintentional Unknown/ Unspecified 96,304	Unintentional Other Bite/Sting 1,142,130
10	Unintentional Poisoning 3,459	Unintentional Poisoning 37,493	Unintentional Unknown/ Unspecified 32,336	Unintentional Other Transport 40,876	Unintentional Unknown/ Unspecified 122,980	Unintentional Unknown/ Unspecified 120,116	Unintentional Unknown/ Unspecified 98,759	Unintentional Unknown/ Unspecified 95,913	Unintentional Unknown/ Unspecified 78,898	Unintentional Other Transport 79,829	Unintentional Unknown/ Unspecified 755,567

*The "Other Assault" category includes all assaults that are **not** classified as sexual assault. It represents the majority of assaults.

Data Source: NEISS All Injury Program operated by the Consumer Product Safety Commission (CPSC).
Produced by: National Center for Injury Prevention and Control, CDC using WISQARS™.

Centers for Disease Control and Prevention
National Center for Injury Prevention and Control

About 1.4 million of the accidental fall injuries were so serious that they required hospitalization with associated annual medical costs of $72.6 billion and work loss costs of $10.5 billion, totaling an overall annual combined economic cost $83.1 billion in 2019, not including an estimated quality of life loss of $264 billion.

Accidental falls are also the third leading cause of unintentional injury deaths in the population, about 39,443 fall deaths in 2019. The associated medical costs were $1.48 billion and the cost of statistical life was $153.7 billion.

MEDICAL IMPACT AND COSTS FOR THE ELDERLY, THE GROUP THAT IS BY FAR THE MOST AFFECTED BY ACCIDENTAL FALLS

Although the vast majority of the elderly are not active athletically, many suffer from plantar fasciitis and other common foot problems. Consequently, the use of athletic shoes is widespread among the elderly for the added support and cushioning that they provide compared to more traditional street or dress shoes, especially high heel shoes.

Nevertheless, fall injuries are a singular problem for the elderly, for which not only has there been no effective solution so far, but falls resulting in death have increased by 30% in recent years.[28] About 36 million older adults fall each year. For the elderly (defined as 65 or older), this included over 2.1 million accidental fall injuries treated in hospital Emergency Department visits in 2019. That total for elderly fall injuries is about 10 times greater than the next leading cause of elderly Emergency Department visits. Those elderly falls had a medical cost of $17.8 billion and work loss cost of $4.7 billion, as well as a quality of life loss cost of $260 billion.

Another 981,951 elderly were injured from their falls so severely that they required hospitalization, with an associated medical cost of $51 billion and work loss cost of $7.3 billion, as well as a quality of life loss cost of $187.9 billion.

According to the **CDC**[3], accidental falls are also the leading cause of accidental deaths in the U. S. for the elderly, **34,212 fall deaths annually**. **That total for elderly fall deaths is over 4 times greater than the next leading cause of elderly accidental deaths. The elderly account for about 82% of all fall deaths.** The medical costs associated with these deaths are $1.35 billion and a lost value of statistical life of $97.2 billion.

The total annual medical cost of falls for the elderly for ED visits, hospitalization, and death in 2019 was $70 billion and a work loss cost of $12.1 billion, as well as a quality of life loss cost of $448 billion. Among the elderly, about 70% of the fall injuries were sustained by females. Many of the fall injuries were major, include fractured hips and traumatic brain injuries.

REMARKABLY HIGH TOTAL COSTS FOR ALL U. S. FALL INJURIES

The total 2019 direct economic cost for all U. S. unintentional falls was $154 billion for emergency department visits, hospitalization, and deaths, including $129 billion in medical costs and $25 billion in work loss costs. In addition, the loss from fall deaths of the value of their statistical lives was $153.7 billion, the loss of quality of life from hospitalizations was $264.1 billion, and the loss of quality of life from ER visits was $649.3 billion, as reported by the CDC.[3]

It is logical to conclude that an unknown but probably significant portion of these accidental fall injuries and deaths, and their direct and indirect financial and non-financial costs, were caused by the inherent instability of conventional footwear soles. The costs are avoidable, since they are due directly to the artificial instability of modern footwear, not to the natural ankle joint and bare foot, which are inherently robust and accidental injury-free in comparison.

Obviously, it is incumbent on the footwear industry to act as quickly as possible to prevent as many of these fall injuries as are caused by the footwear sole defect. The portion is currently unknown, but it seems certain that it must be so significant as to require immediate industry action, given the extraordinary magnitude of the accidental fall injury costs summarized above. Thousands of deaths are preventable and many billions in medical and other costs are avoidable.

THE ANNUAL U.S. ECONOMIC COST OF PREVENTABLE FALLS DWARF THE TOTAL WORLDWIDE ANNUAL SALES OF THE ATHLETIC FOOTWEAR INDUSTRY

To put this in context, the total world-wide annual sales of athletic shoe industry is roughly about **$82.5 billion** in 2021.[4] It is shocking to note that the pre-pandemic 2019 total annual medical and work loss cost alone of unintentional falls in the U. S. alone of **$154 billion** is almost twice the total worldwide annual branded athletic footwear company sales, even though the fall cost omits over $800 billion in costs due to quality of life and statistical life value losses.

Furthermore, total U.S. annual branded athletic footwear sales was only **$31.2 billion**, which is only about 20% of the U.S. annual medical and work lost costs of $154 billion.

If only half of the unintentional falls that resulted in 6,460,000 hospital ER visits, 1,400,000 hospitalizations, and 40,000 deaths annually in the U.S. are caused by the inherent artificial instability of conventional footwear soles – which I believe to be a reasonably conservative estimate – then the direct economic cost alone of those accidental falls in the U.S. each year of about **$77 bi**llion is almost as great as the total world-wide annual sales of the branded athletic footwear industry of **$82.5 billion**.

Furthermore, even if the remaining half of accidental falls were due to falls caused by lack of barefoot traction on slippery artificial surfaces, particularly like those in the bathroom or on stairs – also quite reasonable – then those falls are unavoidable because of the existing instability defect in all conventional slides, sandals, or other footwear that might otherwise be used to prevent the barefoot slips. All currently available footwear options, such as for "shower slides" with rubber soles, that would provide reliable traction on a wet surface also have inherently unstable conventional soles, as previously described.

Therefore, putting grippy shower slides on slippery bare feet in the bathroom is only trading a known traction problem for a now known stability problem, with the probable result being no net change in the number of accidental falls. So, I believe that it is reasonably logical to conclude that eliminating the traction problem using conventionally unstable footwear today will only result in, ironically, unstable footwear soles artificially causing closer to all accidental falls, either directly or indirectly, leading to almost 6,460,000 hospital ER visits, 1,400,000 hospitalizations, and 40,000 deaths annually at a total U.S. direct economic cost of $154 billion.

To put that terrible annual level of 2019 accidental fall fatalities in perspective, its projected total of 800,000 for two decades is 60% greater than the total number of deaths due to the opioid crisis, which was 500,000. However, only the fall deaths also occurred in all of the previous decades at a high level.

Falls due to tripping over foreign objects or to drug impairment might seem to be the only categories of falls that are not be attributable to the shoe instability defect. But even in those cases, the potential for recovery of balance from the fall-initiating trip or drug impairment is obviously made more difficult by the instability defect, so it would seem likely that few falls are entirely unrelated to the sole defect.

Directly or indirectly, then, it seems reasonable to conclude that artificially unstable conventional shoes could well be responsible for most fall accidents. If so, then only by solving the artificial instability problem of conventional footwear can most of the tragic total of accidental falls be prevented and their associated costs be eliminated.

It should be emphasized that if my middle estimate of the U.S. direct medical and work loss cost of $77 billion or more recurs each year, then those avoidable economic costs accumulate year after year, reaching a total of roughly $800 billion wasted every decade. If so, based on **CDC** health statistics[3], my middle estimate is that the defective stability of conventional shoe soles directly causes about 32 million hospital emergency room visits, 7 million hospitalizations and 200,000 deaths each decade in the U. S. – all probably preventable!

Recognizing the extraordinary possibility that unstable conventional footwear could actually be responsible for most accidental falls – the worst case estimate described above – then a total of about $1.6 trillion is wasted in the U.S. each decade, those direct economic costs associated with 64 million hospital emergency room visits, 14 million hospitalizations and 40,000 deaths each decade – again, nearly all probably could be prevented!

I believe that allowing an artificial pandemic of this magnitude to continue is unthinkable when it is can be prevented with relatively little difficulty or cost! To put in relative perspective those astoundingly high economic costs of such a trivial-looking footwear defect, the Affordable Care Act (ACA) was estimated recently to cost U.S. taxpayers about $1.8 trillion over the next decade.[28A]

Whereas there is no consensus on how to lower or eliminate that additional cost of the ACA, fixing the footwear stability defect is relatively simple, reasonably quick, and essentially self-financing, and could roughly offset all of the ACA cost increase. Consequently, I believe the footwear industry must dedicate itself to eliminating the sole stability defect as soon as possible.

WORLDWIDE COSTS AND DEATHS CAUSED BY THE INSTABILITY DEFECT OF SHOE SOLES

As extraordinarily high as these economic costs are, they are for the United States of America alone. Estimating costs for the rest of the world is extremely difficult to do with accuracy, particularly given the large differences between developed and undeveloped countries in medical care and its costs, as well as the varying portion of their populations typically wearing defective footwear.

For example, China with its huge population is still officially considered a developing country, but a majority of its population are certainly wearing footwear with the stability defect (and very few are still barefoot), although primary health care available to treat accidental falls is apparently not yet well developed.

Nevertheless, it is still possible to estimate on a reasonably logical basis with some degree of confidence, at least in terms of the gross overall magnitude. It is almost a certainty that the "developed" portion of the worldwide population that wears defective footwear is at least half of the current population total of 6.85 billion. On that same basis, the estimate for worldwide deaths would be about ten times that of the U.S. alone, or about 200,000 deaths every year or about 2,000,000 deaths each decade.

A rough guesstimate of medical care costs for that "developed" population as defined is only about 25% of the costs of that in the U.S. Based on that assumption, the middle guesstimate for overall medical costs worldwide of the correctible instability defect of footwear would be about $650 billion every year or about $6.5 trillion every decade. I believe that all of these deaths and medical costs, whatever the actual number, however large, are preventable at trivial cost.

THE FOOTWEAR INDUSTRY SHOULD IMMEDIATELY CORRECT THE BASIC DEFECT IN THE DESIGN OF FOOTWEAR SOLES

Of course, the footwear industry should do the right thing. I believe that the relative financial cost of a one-time general design and manufacturing solution within the footwear industry to the basic problem of the fundamentally defective design of conventional shoe soles of even $1-2 billion or more is miniscule – only about 1-2% – compared to the defect's likely annual U.S. medical and work loss costs that may be as much as $85-190 billion or more. Therefore, I believe that the industry should spare no time or expense to fix this problem. I also believe that failure to act effectively and quickly could be inexcusable.

Moreover, a major one-time cost to the footwear industry of almost any reasonable magnitude would be far more than just paid for within the industry by a substantial increase in sales and profits fed by increased consumer demand for immeasurably more stable and comfortable footwear. It is an enormous win-win situation for both producers and consumers!

This seems like a rare open and shut case requiring immediate industry-wide action. The irrefutable simple evidence provided by the **Standing Ankle Sprain Simulation Test**, verifiable by any footwear consumer, together with the **CDC** data on unintentional falls, leave no room for reasonable doubt about the need for action without delay. It is not a close call. This is a classic case in which continued failure is not an option. How best to avoid so many needless deaths as quickly as possible, as well as so much pain and suffering, together with the massive medical care and other associated costs, is the only issue.

It seems now crystal clear that the previously hidden structural defect of conventional shoe soles causes a serious medical problem, not the human ankle that has taken the blame until now. The artificially-induced costs of the shoe sole defect are avoidable without substantial difficulty for the footwear industry, for which implementing the feasible safe sole solution as described above must be, of necessity, an immediate all-hands-on-deck industry-wide operation. Any significant delay in industry-wide action will almost certainly invite outside intervention by government or other legal authorities on the state or Federal level, which would likely slow actual progress in fixing the problem and increase the cost of doing so.

Now in possession of the indisputable facts that has been demonstrated in full detail here, the only responsible option for the footwear industry is to act with clear determination to fix this well-hidden but correctible problem to the best of their ability and to do so without delay.

Especially since there are some relatively easy and inexpensive short cuts!

A VITAL QUICK FIX TO CONVENTIONAL SHOE SOLES: REMOVE THE LATERAL MIDFOOT INDENTATION DEFECT

As seen in **FIGURE 50**, which shows a **Dynamic Footprint** superimposed on the outline of a conventional shoe sole, the largest mismatch between the footprint of the fully supinated foot and a conventional shoe sole is in the midfoot centered around the position of **the base of the fifth metatarsal bone**, located between the forefoot and heel portions (and indicated by the arrow),

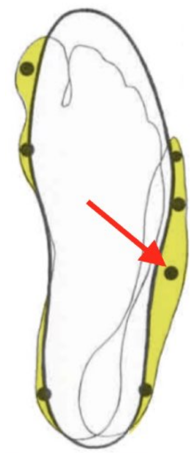


FIG. 50

Most conventional shoe soles have an insidious weight-savings feature, the **indentation at the lateral midfoot**. This simple lack of direct structural support allows the base of the fifth metatarsal of the wearer's foot to initiate unnatural lateral instability, because it is the first part of the wearer's foot sole to roll off the lateral side of the shoe sole. Because of the indentation, it is also the part of the wearer's foot which rolls the farthest off that lateral side during extreme supination.

The structural indentation at the lateral midfoot of a conventional shoe sole therefore artificially increases an already critical stability problem. In effect, the structural indentation functions as the **trigger** of unnatural lateral instability that starts the artificial tilting sequence of the shoe sole that can quickly culminates in a lateral ankle sprain or break and fall.

This **lateral midfoot indentation defect** is unfortunately a standard feature of nearly all conventional shoe soles, and is a particular problem in modern athletic shoes. Almost all include deep lateral midfoot indentations with highly sculpted midsoles and outsoles, which in **FIGURE 88A** are shown next to a **straight red bar** in underneath sole views of many current basketball shoes, all endorsed and worn by current or former professional basketball superstars, starting with the latest Nike Air Jordan XXXVI and also a 1920's classic Converse Chuck Taylor All Star. The last three sole views of **FIGURE 88A** are current running shoes. Most classic everyday non-athletic street or dress shoes also leave the 5th metatarsal base completely unsupported.

Therefore, the first step that should be taken by the footwear industry, one that is relatively quick and easy to do, should be to undertake corrective action to remove the now-obvious trigger of unnatural instability of the conventional sole. That simple structural fix is to **eliminate the deep indentation in the lateral midfoot portion**, forming thereby a **straight line** on the lateral side between the outermost edges of the lateral forefoot and lateral heel.

Fig. 88A

The result of eliminating the indentation on the midfoot lateral side of the conventional sole is shown by the **midfoot lateral sole extension** in **FIGURE 88B**, shown here **in red** in a perspective view and also in an overhead schematic view as an additional feature to the conventional shoe sole shown **FIGURES 49** & **50**. As shown, the upper surface of the sole extension is located outside of the shoe upper.

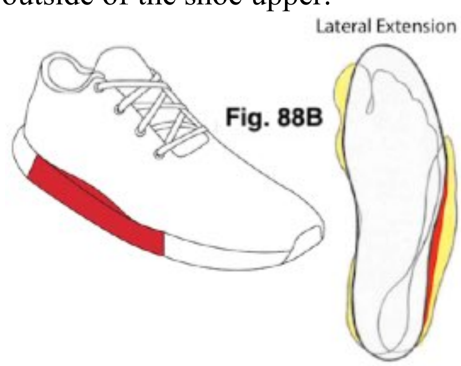
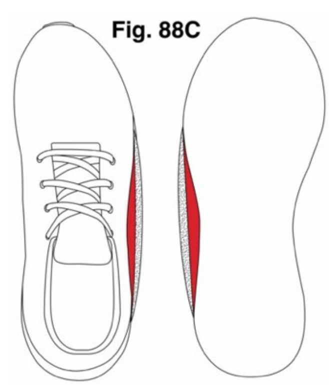


Fig. 88B

The **midfoot lateral sole extension** provides much better support for the base of the 5th metatarsal bone in normal loadbearing and particularly during excessive supination, so that it does not lead the foot sole off the shoe sole. The rest of the conventional shoe sole remains completely unchanged in structure, outward appearance, and functionality.

Although only a partial measure, it is easy to do and can be made without the dangerous delay inherent in more comprehensive corrections. The lateral stability of any conventional shoe design, especially classic ones with a relatively flat bottom sole, can be significantly improved by simply eliminating the indentation of the lateral midfoot portion of the shoe sole. Doing it is a risk-free no-brainer.

Fig. 88C



It should be noted that the lateral indentation is often deeper on the lower, ground-contacting surface of the conventional shoe sole than on the upper, foot contacting surface, as seen in **FIGURE 88C**. So, the **midfoot lateral sole extension** must be structured to match this difference. It is preferably a minimal extension with a straight or flat side, as shown **in red** – <u>not</u> projecting out farther in a bulge shape, as shown in the speckled portion.

This recommendation is based on some early development and testing at **i-generator** that experimented with several different widths of the **midfoot lateral sole extension**. Although that initial work was somewhat crude, the results seemed to indicate conclusively that the optimal **midfoot lateral sole extension** was simply to eliminate the indentation between heel and forefoot, but without projecting it farther into an outward bulge. That is, the **midfoot lateral sole extension** should extend only as far as a border indicated by the straight yellow line shown in **FIGURE 88D** to provide the greatest overall stability benefit and to do so with the least effort or structural change. In other words, the biggest bang for the buck.

Moreover, making the lateral extension into a wider bulge shape has a stability disadvantage. Although a wider outward bulge extension initially resists tilting, it increases instability in the extreme supination that results in ankle spraining.

Initially, a wider **midfoot lateral sole extension** that bulges out beyond the straight yellow line provides greater resistance to rollover when a conventional shoe sole is flat on the ground, as seen in **FIGURE 39A**. And if the shoe sole is only moderately tilted, a positive stabilizing torque is created by the longer lever arm of the bulging midfoot extension that resists further tilting, as seen in **FIGURE 39B**.

However, if the angle of tilt reaches the **tipping point of about 20°**, as seen in **FIGURE 39C,** or if that **20°** angle of tilt is exceeded, as seen in **FIGURE 39D,** such as when a player steps on another player's foot, the extra width becomes a major structural liability. The wider bulge increases the artificial lever arm, making it longer, which causes the bodyweight force (or often multiples thereof) to create a powerful destabilizing torque focused at the lateral midfoot, stressing it, that pushes the shoe sole over, out of control, spraining or breaking its wearer's ankle and producing a fall that could have serious injuries.

The simplest possible construction methods were used to construct the ad hoc prototype shown in **FIGURE 88D**. The **midfoot lateral sole extension** was made from glued-on midsole material (typically available in sheets with varying thickness and material density) that was belt-sanded to the desired shape. The material used was selected to match as closely as possible the characteristics of the shoe sole's midsole, omitted a separate outsole for construction simplicity.

Although necessarily a subjective evaluation at this early stage, it is likely to be the correct one, because that minimal but crucial elimination of the indentation definitely provides the critical missing direct structural support to the base of the 5th metatarsal bone. Moreover, initial research testing at **i-generator** indicates that a definite increase in lateral stability is readily apparent to a blinded test subject of a shoe model with the **midfoot lateral sole extension** (like the straight yellow line extension shown in **FIGURE 88D**) compared to the unmodified model when tested in the **Standing Ankle Sprain Simulation Test**.

This early research result is particularly significant, since the necessary rigor of blinded tests is normally missing in biomechanical studies of athletic footwear. **FIGURE 88D1** shows the Nike ***Pegasus*** running shoes with both **midfoot lateral sole extensions** – straight sided (white) and bulging out (pink) – that were used for testing at **i-generator** in comparison to an unmodified ***Pegasus*** shoe, shown in FIGURE 88A (second from last).


Fig. 88D1

Added to the benefit of this normally missing scientific rigor is the ease of replication, which is another critical component of valid scientific testing that also is almost always missing in biomechanical studies of athletic footwear. The standing ASST is so simple, the only equipment necessary to conduct it is the shoe model pair including one with an easily constructed **midfoot lateral sole extension** to use for comparison with the unmodified one. Almost anyone can replicate the results without difficulty.

In addition, **i-generator** conducted comparison testing between a wide variety of modern basketball shoes that had been modified with the straight-sided **midfoot lateral sole extension** and unmodified shoes of the identical shoe model. They included the Nike ***Air Jordan XXXVI***, Nike ***Zoom Freak*** 3, Nike ***Zion 1***, Under Armour ***Curry Flow 8***, and Adidas ***D.O.N. Issue #3***, as well as the classic Adidas ***Superstar*** and Converse ***All-Star***. The lateral stability of all of the shoe models was improved, with variation between models and test subjects.

Another modern basketball shoe proved to be the lone exception. The Nike ***LeBron 19*** could not be modified because it already features unique direct structural support under the base of the 5th metatarsal and is already more stable than the others in lateral midfoot stability testing. **FIGURE 88D2** shows the modern basketball shoes that were modified by **i-generator** with the straight-sided **midfoot lateral sole extension**.


Fig. 88D2

The meaningful improvement in lateral stability from this radically simple fix would have little effect on the conventional look of the shoe sole (see examples of two running shoes and a basketball shoe shown in **FIGURE 88E**. Nevertheless, it should make a measurable improvement in reducing the incidence of lateral ankle sprains, breaks, and falls.

Fig. 88E

The straight-sided **midfoot lateral sole extension** is shown **in red** for contrast here, but can obviously be the identical color of the shoe model, as well as the same material, as the midsole or outsole components of which it would then be a nearly invisible extension. **FIGURE 88E1** shows such a modification to an example Nike ***Pegasus 38*** running shoe.

As shown, the stock ***Pegasus 38*** shown in FIGURE 88A was modified as shown in FIGURE 88D1 with a straight side and then hand-smoothed, trimmed, and painted, with some final ***Photoshop®*** finishing touches, to produce a simulated production ***Pegasus 38*** as it would look with a straight-sided **midfoot lateral sole extension**. As indicated here, in actual production, the change would be almost invisible, except in a bottom view.

Fig. 88E1

This is definitely a very worthwhile interim improvement, and relatively easy and inexpensive to implement, since it does not appear to otherwise alter the appearance or the performance of other functions of existing conventional shoes.

Although its precise level of effectiveness is unknown at this initial stage of development, it seems likely to reduce ankle sprains, breaks and falls, especially during walking and standing, perhaps by as much 25%. The effectiveness is likely to be even greater among the much less active elderly, where such injuries are most prevalent, as discussed earlier,[24A] with a potential reduction of as much as 50% from this simple fix. So, it is a very simple modification with an extremely important potential safety benefit. However, it is only likely to lower the incidence and severity of lateral ankle sprain, break, and fall injuries to a much lesser degree for all the more rigorous activities common in athletics.

The same limitation exists if the **midfoot lateral sole extension** is also extended into the forefoot area to support the head of the fifth metatarsal, which carries the peak load in the lateral ankle spraining position, as previously seen in FIGURE 72. Although the increased width proximate to the head of the 5th metatarsal is very useful to risk tilting, it is of course a more significant structural change, increasing as it does the overall width of the forefoot of the shoe sole and, after the tipping point is reached, drastically increases instability by increasing the lever arm. Consequently, its use as a quick fix is very limited. It is definitely more preferable for the extra sole width in the forefoot to be included within the shoe upper, rather than outside it, and should preferably equal the width of the wearer's forefoot, not exceed it.[29]

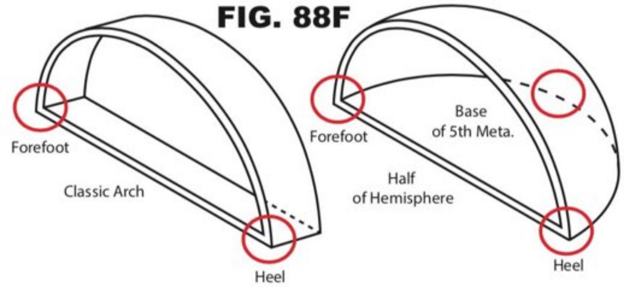
It should be noted here that the **midfoot lateral sole extension** is an add-on feature that is external to the shoe upper, which matches the shape of the wearer's foot, which is indented when standing upright (but definitively not in extreme supination). Therefore, the extension is outside of the shoe upper. That makes the extension a relatively easy way to implement a substantial stability improvement.

In addition, to be maximally effective, the **insole or sock liner** of the conventional shoe must also be similarly modified with an identical elimination of the conventional indentation that parallels the **midfoot lateral sole extension** of the sole. Alternatively, the thickness of the midsole of the **midfoot lateral sole extension** can be increased slightly to compensate for an absence of insole paralleling it.

Finally, it must be emphasized that the effectiveness of taking the extra time and trouble to modify the design of a conventional shoe sole with the **midfoot lateral side extension** should not be viewed as anything more than a necessary quick partial fix. It is just functioning as a finger in a massively leaking dike to reduce an ongoing flood of preventable injuries. It can only be much less than the effectiveness of using a new and much better design that restores the full natural stability of the barefoot sole, as discussed in detail earlier in this book relative to FIGURES 85A-85N and to the ***ARIG Slide***, FIGURES 56 & 57, as well as in my U.S. patents. The lateral extension only removes a defect in most conventional shoe soles, which never can provide stability performance like the barefoot sole or new footwear sole designs based on it.

A brief digression here to make an important point about the overlooked but key role of the base of the 5th metatarsal bone in anchoring the main longitudinal arch of the foot. It is generally misunderstood to be a simple arch with a classic uniform 2D structural shape stretching from the heel to the forefoot. See the Classic Arch in **FIGURE 88F**.

FIG. 88F



However, the main longitudinal arch is actually more like a complex 3D structure shaped like half of a hemisphere, with the base of the 5th metatarsal bone crucially providing direct support in the middle of the arch. See the Half Hemisphere in **FIGURE 88F**. It is therefore absolutely essential for a stable shoe sole to provide direct structural to the base of the 5th metatarsal bone to naturally support the foot's longitudinal arch, unlike conventional shoe soles with their indentation at the midfoot lateral side, an important structural defect.

Logically, as a result of providing better, more natural support, the **midfoot lateral sole extension** should have the additional benefit of preventing or reducing Jones fracture injuries like that which occurred to Kevin Durant, as discussed previously with reference to FIGURE 8. The base of the fifth metatarsal would be supported in a natural way by the midfoot sole extension, instead of being unsupported even when standing upright or walking, much less during running or other athletics, which often includes the extreme supination that occurs in sharp cutting maneuvers in sports and other rigorous activities.

Finally, it is important to consider the proven efficacy of a functionally similar large external device configured as a lateral side extension that straps onto a conventional shoe sole. The device is currently being marketed as the ***Armor1* ankle roll guard** (see www.anklerollguard.com). **[FIGURE 88G]** It is located proximate to the base of the 5th metatarsal bone like the **midfoot lateral sole extension**, although it extends backward partially into the heel area, and is also designed to prevent lateral ankle sprains. However, unlike the **midfoot lateral sole extension**, it is an external device, not integrated into the shoe sole or shoe upper.

Although the ***Armor1*** ankle roll guard design differs from the **midfoot lateral sole extension** structurally, it is sufficiently similar to serve as a reasonably analogous initial **proof of concept** of the general functional effectiveness of preventing ankle sprains with such lateral midfoot structural add-ons to the sole of conventional shoes. Two peer reviewed studies published in 2020 indicate that "… of all the devices (Ankle Roll Guard, Brace, Tape), only the Ankle Roll Guard appears to allow the user normal ankle motion (i.e. typical anatomical joint motion), while preventing excessive ankle inversion," according to the senior researcher from Boise State University, Tyler Brown.[30]

The **midfoot lateral sole extension** can likely be more functionally effective by enlarging it into a structure more like that of the ***Armor1* ankle roll guard**, but fully integrated into the structure of the shoe sole itself, instead of being a strapped-on separate component. The integrated look of such a modified **midfoot lateral sole extension** as an integral part of the shoe sole obviously would be much more aesthetically appealing and more durable as well.

But again, it must be emphasized that undertaking this general approach is a limited measure that reduces the lateral stability problem, but definitely does not restore the full natural stability of the barefoot sole. So, it is a meaningful step to improve in a limited way the stability of conventional shoe designs, but doing any more than simply eliminating the basic indentation defect in them with the midfoot lateral extension may not be cost effective.

Also, doing more in this way is a much more complicated and time-consuming process that is much less effective as a quick fix. More importantly, the limited effectiveness of taking that extra time and trouble would be much less than the much greater effectiveness of comprehensively redesigning the defective structure of conventional shoe soles in order to actually restore the full natural stability of the barefoot sole, as discussed in detail earlier in this book relative to FIGURES 85A-85N and to the **ARIG Slide**, FIGURES 56 & 57, as well as in my U.S. footwear sole patents.

THE QUICKEST POSSIBLE FIX: GET LOCAL COBBLERS TO MODIFY YOUR SHOES (OR JUST DO IT YOURSELF)

Given the utter construction simplicity of modifying existing shoe soles, and also of testing the first modified pair to self-validate the improvement, there is no reason why anyone cannot modify their existing shoes. Most shoe repair shops should be capable of doing the job with only some instruction from you required, or if you have reasonable do-it-yourself skills and equipment, you can just do it yourself, as I did in the late 1970's (discussed next with FIGURES 88H-J).

Certainly, all professional sports teams should at least undertake the simple comparison described above of modified and unmodified shoes typically in use in their sport and determine whether they should undertake their own modification of all of their players' shoe soles, either directly and/or through the shoe companies endorsed by many of their players. The same is certainly true for Division I college teams and potentially any other teams at any level.

THE QUICKEST DESIGN AND MANUFACTURING FIX: A SEPARATE MIDFOOT LATERAL SOLE COMPONENT GLUED TO THE CONVENTIONAL SOLE

Because it is so easy to do, a midfoot lateral side extension like the **midfoot lateral sole extension** was the very first shoe sole modification I ever attempted. In the late 1970's I modified a pair of Adidas **Country** running shoes by gluing on a lateral side extension of similar midsole material, much like the recent sole extension construction shown in FIGURE 88D.

At that time long ago, I was not sure how much sole material to add, so I just added the ¼ inch thickness of the sheet of plastic foam midsole material that was available then (from a shoe repair supplies store quaintly located in an old house in downtown Washington, D.C., near the Capitol and now long gone) and used a belt sander to remove the excess material in the forefoot and heel to blend the extension into the existing sides of the Adidas **Country** running shoe, as shown in **FIGURES 88H & 88I**.

Fig. 88H

Fig. 88I

It was crude, but a discernable improvement in lateral stability, although this early precursor side extension is focused farther forward than the example **midfoot lateral sole extension**, which is centered in about the midpoint between the base and head of the 5^{th} metatarsal bone. As shown in this alternative structure, the **midfoot lateral sole extension** can be positioned so that it bulges outward proximate to both the base and the head of the 5th metatarsal bone. Because of the outward sloping soles of most running shoes of the 70's, more of the lateral extension is on the upper surface, but an overhead view is not shown because only part of the lateral extension is visible since it is substantially obscured by the now stiff leather upper.

At about the same time, I added a similar midfoot lateral side extension to a pair of Adidas' ***1976 Marathon*** racing shoes, shown on the left of **FIGURE 88J** next to a later walking version of the same basic Adidas shoe model, shown for comparison on the right. This example of a midfoot lateral side extension is located farther back, overlapping part of the heel area, closer to the position of the ***Armor1* ankle roll guard**.

Despite the crudeness of the finished products, I think my attempts at making midfoot lateral side extensions in the late 1970's points the way to the easiest possible industry design and manufacturing approach now. A separate midsole piece – call it a **midfoot lateral sole component** – can be structured like **midfoot lateral sole extension** to fit precisely into a conventional shoe sole's lateral indentation. It would function as a plug to fill the gap.

Fig. 88J

It can be molded as a separate piece to attach to a specific size or sizes of a specific model or a more general model of a shoe sole. Alternatively, like FIGURES 88H-J, the component can be made from material attached to the indentation, exactly or generally, and then shaped to fit it as precisely as desired on the outer surface. It can be securely attached with glue or other means, permanently or temporarily, onto any otherwise conventional shoe sole to make it much safer.

As shown in FIGURES 88H-J, the separate **midfoot lateral side component** can also extend into the forefoot area proximate to the position of the head of the 5th metatarsal or distal phalanges of an intended wearer; or it can extend into the heel area proximate to the position of the intended wearer's calcaneus; or it can extend proximate to both forefoot and heel areas. However, as noted before, such forefoot and heel extensions are not preferred, since they inherently increase the unnatural destabilizing lever arm when a conventional shoe sole is tilted past the tipping point.

AN INSTANT FIX: A WEARER OF STANDARD WIDTH SHOES CAN SIMPLY SWITCH TO WIDE SIZE SHOES

Anyone with a normal or standard width foot can try the quickest fix, which is to use a wide or extra-wide size width shoe instead of a standard width size shoe, either of the desired shoe model or the closest available model to it (since fewer shoe models are made in extra width sizes). Similarly, a narrow width size wearer can move up to a standard width size shoe.

The extra interior volume of the larger shoe can be filled with either a thicker pair of socks or a second pair of socks or socks with extra sole thickness (preferably, as long as that extra thickness extends continuously through the midfoot area, not just the forefoot and heel, as is often the case) and/or a wider insole with greater thickness and/or density or an additional such insole from any one of many third party venders like Dr.Scholl's®, potentially cut-to-fit.

Unfortunately, most shoe companies offer only a limited selection of shoe models in wide or extra-wide width sizes, so it may be difficult to get a shoe model the same or equivalent to that which is desired. On the other hand, it would be relatively easy for shoe companies to rapidly expand production of their existing wide size shoe models to meet increase demand, if it occurs.

For an everyday shoe used principally for standing and walking, the functionality of the wider shoe should be at least a minor improvement. However, there is an unavoidable tradeoff in increased weight and reduced feel or response, either or both of which may be very important to a particular wearer in a particular sport or fitness activity.

ADDING IN USEFUL FLEXIBILITY TO THE CONVENTIONAL SHOE SOLE TO BETTER ACCOMMODATE THE OUTWARD TILTED POSITION OF EXTREME SUPPINATION

As shown in FIGURES 13 & 14, the foot is tilted outward in the maximally supinated position in which ankle spraining occurs. It seems logical, therefore, to provide a special axis of flexibility in the conventional shoe sole so that the portion of the shoe sole under the supinated foot can remain flat to support the flattened foot sole as neutrally as if the foot were bare. That **supination flexibility axis** can be located proximate to the footprint made by the supinated foot on the shoe sole. **FIGURE 89** shows that the axis can also be located in the area in which the maximal supination footprint and maximal pronation footprint overlap. The flexibility axis can also be straight and next to the supination footprint. It can be curved, including in parallel with the shape of the extreme supination footprint or the extreme pronation footprint.

Fig. 89

To avoid forcing the supinated foot to roll outward on the shoe sole, the supination flexibility axis also can be positioned to extend medially. The supination flexibility axis can be formed from midsole and/or outer sole material with increased flexibility from a lower relative density as measured on the Asker C durometer scale, for example, and/or with structural flexibility created by using less material, such as in the outsole/midsole tread pattern and/or outsole/midsole channels and/or sipes. The Nike **Free** model soles are a general example of the use of such sipes in the form of slits or channels originating in the bottom surface of the shoe sole.

In addition, as shown in FIGURES 49 & 88, the relative motion of the barefoot sole on the shoe sole during maximum supination is much greater in the forefoot, particularly and also the midfoot, compared to the heel. Also, during extreme supination, when the calcaneus of the barefoot tilts substantially, but the heel remains flattened by deforming, while the midfoot and forefoot become tilted outwardly, as shown in FIGURE 13, although both also flatten by deforming only under the base and head of the fifth metatarsal bone. Consequently, the supination flexibility axis can be located only in the midfoot and forefoot or have greater flexibility provided in those areas by the differential use of material or structural flexibility using sipes, as just described.

Also, since it can exclude the heel area, the supination flexibility axis can be located more laterally, into the position of the shank described in Endnote **29**. The functional goal would be to enable the shoe sole forefoot and midfoot to tilt naturally like the barefoot in the extreme supination position without forcing the shoe sole heel to tilt also, since the shoe heel should remain flat to parallel the barefoot heel's continuous flattening throughout the full range of motion of the calcaneus tilting, as enabled by the subtalar joint.

In the lateral ankle spraining position in a conventional shoe sole, the forefoot unnaturally torques the shoe heel over, as seen in FIGURE 16 (page 26), unlike the tilted barefoot in the same position, as seen in FIGURE 15 (also page 26). Therefore, another, similar approach is to create a midfoot flexibility zone to uncouple the tilted forefoot from the heel, so the heel can remain flat. That can be done, for example, with deep Nike Free-type sipes or relatively flexible sole and midsole material in most or nearly all of the sole's midfoot area. Only the support area under the base of the fifth metatarsal needs to be as firm as the forefoot and heel areas.

A NEUTRAL DESIGN FOR A REASONABLY WIDER AND SOMEWHAT MORE STABLE CONVENTIONAL SHOE SOLE FOR NON-ATHLETIC USE

In contrast to FIGURE 55, an odd-looking design exercise that shows a conventional running shoe with full side sole extensions for both extreme pronation and extreme supination, it is possible to design a conventional shoe sole with more reasonable, less extreme side extensions. As shown in **FIGURE 90** as the blue hatched areas that are added to a bulging **midfoot lateral sole extension**, those less extreme side extensions still provide much improved neutral stability during pronation and supination.

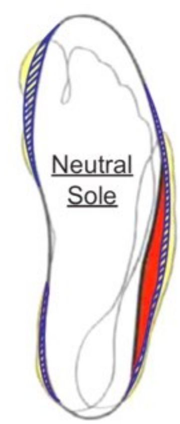


FIG. 90

This neutral sole design is however only useful for an everyday shoe for walking and standing, and less preferably for running. It is much less preferable for fitness and athletics that involve frequent lateral motion because they inherently increase the unnatural destabilizing lever arm when a conventional shoe sole is tilted past the tipping point.

Also, as noted earlier, the effectiveness of taking the extra time and trouble to do this would be much less than the effectiveness of comprehensively redesigning the defective structure of conventional shoe soles in order to actually restore the full natural stability of the barefoot sole. That can be done by incorporating it into the barefoot-like sole designs discussed in detail earlier in this book relative to FIGURES 85A-85N and to the **ARIG Slide**, FIGURES 56 & 57, and in my issued U.S. patents.

As noted before with the wider **midfoot lateral sole extension**, these extra width sole side extensions provide greater resistance to rollover when the conventional shoe sole is flat on the ground, as seen in **FIGURE 39A**. And if the shoe sole is only moderately tilted, a positive stabilizing torque is created, as seen in **FIGURE 39B**. But if the angle of tilt reaches the tipping point of about 20°, seen in **FIGURE 39C,** or is exceeded in **FIGURE 39D**, such as when a player steps on another's foot, the extra width becomes an extreme structural liability. It increases the artificial lever arm, making it longer, which enables the bodyweight force (and often multiples thereof) to create a powerful destabilizing torque that pushes the shoe sole over out of control and spraining or breaking its wearer's ankle.

So, again, it must be emphasized that all of these limited sole side extensions added to conventional shoe soles are literally just a stop gap measure that reduces the basic instability problem somewhat, but does not fundamentally fix it. Use with athletic shoes other than running shoes is not recommended. The extra sole side extensions approach is not even a halfway measure, but it can be done quickly at little cost or risk, so it may be a worthwhile step to take in the short term to improve conventional shoe designs already in production.

A WIDER, SOMEWHAT MORE STABLE CONVENTIONAL SOLE DESIGN FOR A SUPINATOR WEARER

The same important caveat applies here as with all conventional sole designs with extra width. Use with athletic shoes other than running shoes is not recommended.

To provide a wider conventional shoe sole for an intended wearer who would be characterized in conventional terms as a "**supinator**", the increase in sole width can be positioned on the lateral side that is added to the **midfoot lateral sole extension** as shown in **FIGURE 91A**.

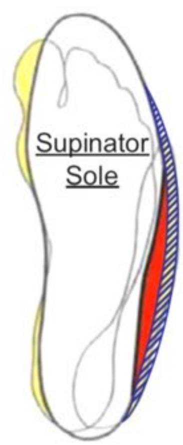


FIG. 91A

Like the **midfoot lateral sole extension**, a **lateral supinator extension** can be located outside of the shoe upper. Alternatively, the additional lateral width can be partially or fully located within the shoe upper, with the **midfoot lateral sole extension** remaining outside the upper.

The resulting wider shoe sole would have the overall shape that is conventionally characterized as a **curved last** shoe. The result is a wider, more stable shoe sole that is "tuned" for intended wearers who are supinators, but that is still substantially less wide than a shoe sole that is as wide as the dynamic footprint [FIGURES 49 & 55].

It is worth repeating for emphasis that this lateral side sole extension is literally just a stop gap measure that reduces a stability problem somewhat, but definitely does not fix it or come anywhere close to fixing it. It is not even sufficiently effective to be called a halfway measure, but it can be done relatively quickly and easily at little cost or risk, so it may be a cost effective way in the short term to improve conventional shoe designs already in production.

As noted earlier, the limited effectiveness of taking the extra time and trouble to modify the design of a conventional shoe sole would be much less than the much greater effectiveness of integrating the **lateral supinator extension** into a new and much better design that restores the full natural stability of the barefoot sole. That can be done by incorporating it into the barefoot-like sole designs like the new sole designs discussed in detail earlier in this book relative to FIGURES 85A-85N and to the **ARIG Slide**, FIGURES 56 & 57, and in my issued U.S. patents.

A WIDER, SOMEWHAT MORE STABLE CONVENTIONAL SOLE DESIGN FOR A PRONATOR WEARER

The same important caveat applies here as with all conventional sole designs with extra width. Use with athletic shoes other than running shoes is not recommended.

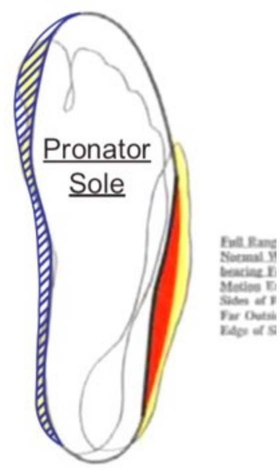


FIG. 91B

To provide a wider conventional shoe sole for an intended wearer who would be characterized in conventional terms as a "**pronator**", the increase in sole width can be positioned on the medial side, as shown in **FIGURE 91B**.

Like the **midfoot lateral sole extension**, the **medial pronator extension** would be located outside of the shoe upper. Alternatively, the additional medial width can be partially or fully located within the shoe upper, with the **midfoot lateral sole extension** remaining outside the upper.

The resulting wider shoe sole would have the overall shape that is characterized as a **straight last** shoe. Note that the **midfoot lateral sole extension** located on the lateral side is retained. The result is a wider, more stable shoe sole for pronators, but that is still substantially less wide than a shoe sole that is as wide as the dynamic footprint [FIGURES 49 & 55].

It is worth repeating again for emphasis that this medial side sole extension is only a stop gap measure that reduces an instability problem somewhat in the short term, but definitely does not fix it nor come anywhere close to eliminating it. It is not effective enough to be called a halfway measure, but it can be done relatively quickly and easily at little cost or risk, so it could be a reasonable approach to improve conventional shoe designs already in production.

But again, the same important caveat applies to all conventional sole designs with extra width. Use with athletic shoes other than running shoes is not recommended. The limited effectiveness of taking the extra time and trouble to modify the design of a conventional shoe sole would be much less than the much greater effectiveness of integrating the **medial pronator extension** into a new and much better design that restores the full natural stability of the barefoot sole. That can be done by incorporating it into the barefoot-like sole designs like the new sole designs discussed in detail earlier in this book relative to FIGURES 85A-85N and to the **ARIG Slide**, FIGURES 56 & 57.

CONCLUSION

The conclusion to be drawn from my multi-decade investigation, briefly summarized in this book, is as simple as the very basic science on which it is based. I believe that it cannot be overemphasized that the simple **Standing Ankle Sprain Simulation Test** provides a crystal-clear minimum standard by which any shoe sole design can be accurately measured to ensure that it provides reliable safety during extreme supination and pronation to avoid most ankle sprains and breaks, as well as falls with many related injuries, many quite serious.

The **Standing Ankle Sprain Simulation Test** is therefore the key tool that is essential to ensure that the footwear industry is enabled to easily design and develop new and far safer, more stable footwear. Every new shoe sole design should be tested with the **SASS Test** at every important stage of sample development. Any pre-production sample that fails the **SASS Test** should be withheld from production until and unless it can be modified to pass the **SASS Test**.

The bare sole of the human foot has been revealed by the **SASS Test** to be stable even at the extreme limit of normal subtalar joint supination. That inherent natural stability proves beyond reasonable doubt that the gross instability consistently demonstrated by conventional shoe soles in the **SASS Test** can only be caused artificially by the inadvertently defective basic design of the conventional shoe sole, one that is literally ancient.

My numerous prototypes and pre-production samples spanning many decades have shown conclusively in extreme foot supination testing conditions that the artificial conventional shoe sole instability can be avoided (even in extreme **7G** conditions that go substantially beyond the controlled **½ G** condition of the **SASS Test**). In fact, the artificial instability of conventional shoes can be quickly and meaningfully reduced with little effort or cost for non-athletic uses like walking with the **midfoot lateral sole extension**. Instability can be effectively eliminated in athletic shoes, although that more comprehensive effort requires considerable time, effort, and expense.

The added expense should easily be self-financing from multi-year windfall profits within the footwear industry from the sale of much more stable shoes with much better comfort. With the initial guidance I have provided in this book, Nike, Adidas, and the multitude of other athletic shoe companies can lead the rest of the footwear industry in developing commercial footwear products with barefoot-like extreme stability and barefoot-like comfort.

The simple facts made obvious by the **SASS Test** strongly indicate that a close connection of unknown magnitude exists between the innately dangerous instability defect in conventional shoe soles and an enormous toll of accidental falls every year. According to the **CDC**[3]**,** those falls result annually in about 6,460,000 Emergency Room visits, 1,400,000 hospitalizations, and 40,000 deaths, with a total direct economic cost of $154 billion in just the U.S. alone, compared to annual athletic footwear sales of about $70 billion.

Those 40,000 fall deaths projected for two decades is 800,000 or about 60% more than the total deaths in the past two decades caused by the opioid crisis, 500,000. Moreover, unlike the opioid deaths, that high level of fall deaths continued for the decades prior to 1999.

Whatever the actual number of those falls caused by the instability defect of conventional footwear soles annually, even a minimal estimate constitutes a major medical catastrophe, a truly epic national tragedy recurring each year in slow motion. And the actual number of falls caused by the sole defect is likely to be significantly worse than the minimum estimate.

Incredibly, then, it seems apparent now that this unnatural footwear instability has caused an invisible worldwide plague of easily preventable accidental falls and the serious injuries that result from them. An invisible catastrophe of extraordinary magnitude has been ongoing worldwide, year after year, decade after decade, generation after generation.

But it is invisible no more. Given the newfound understanding presented in this book of the apparent medical emergency, as well as sufficient knowledge of how to end it without undue difficulty or unreasonable cost, I believe that the global footwear industry has an urgent and inescapable duty to use whatever of its resources and expertise are necessary to meet and overcome this unexpected challenge, one that will likely define the industry.

It is also an extraordinary opportunity, with associated costs but tremendous potential benefits for both the industry and its consumers. Acting voluntarily now with the appropriate speed and intensity, Nike, Adidas, and the rest of the footwear industry can ensure that its future footwear products are finally made safe for their intended use by the public.

ACTION BY THE FOOTWEAR INDUSTRY IS NECESSARY AS QUICKLY AS POSSIBLE

I believe that there is no need to wait for laborious formal studies to be completed over many years by scientific experts nor for formal company action plans to be debated in excruciating detail at every organizational level. Future research is only likely to further confirm and elaborate the uncomplicated proof of the inherent instability of conventional shoe soles shown in this book, not overturn it.

I believe that the simple proof of serious footwear instability presented here, easily replicated by anyone, is beyond serious challenge, and, together with the CDC's fall injury data, is beyond a reasonable doubt sufficiently compelling to make necessary the straightforward actions for the footwear industry like those proposed in **APPENDIX 1** to be implemented now.

In this highly unique situation, I believe that the risk for the footwear industry of acting too slowly is far greater than the risk of acting too quickly.[31] I think that the serious conventional footwear stability problem should be formally acknowledged immediately by the footwear industry and action undertaken as soon as possible to solve it. Any delay will likely only make solving the problem more difficult, with potentially many more parties from outside of the footwear industry involved in the process. Significant delay could make solving the problem far more difficult.

Any decision should be made while bearing in mind that even the lowest, **10%** estimate of the fall injuries and related financial costs apparently due to the footwear instability problem is, each year, an avoidable international medical disaster. Without swift and effective corrective action, failure to solve the instability problem has the obvious potential to seriously damage the footwear industry.

On the other hand, I believe that if the leaders of the footwear industry act quickly and effectively on their own volition to solve the heretofore hidden instability problem, that bold initiative will allow it to take on a positive role for its consumers as a critical problem solver instead of a problem maker. Doing so will also open up a huge potential commercial opportunity, since footwear with new, much more stable soles, as well as more comfortable, will likely increase sales substantially for many years.

I firmly believe the entire footwear industry, but especially the athletic shoe industry and its leaders, are now at a critical tipping point because of the unexpected but likely magnitude of the serious injury effects of the instability sole defect. To end on a poetic analogy, I think the instability defect has now put every shoe company at a fork in their road forward of the sort described by Robert Frost in his famous poem, "***The Road Not Taken***." Directly ahead of each company now is an inescapable decision: either ignore the defect and/or defer timely action <u>or</u> acknowledge it quickly and work hard to correct it. I believe which way each individual company chooses to go will likely determine its future.

PREVIEW OF MY SECOND BOOK:

UNNATURAL DEFORMITY:
An Unprecedented Medical Catastrophe
Hidden In Plain Sight For Centuries

THE MODERN HUMAN BODY HAS BEEN CRITICALLY DEFORMED BY ORDINARY ELEVVATED SHOE HEELS

Nearly all athletic and other shoes have elevated heels, which new and exceptionally reliable scientific evidence indicates supinate the **subtalar joint** of each foot unnaturally. As a result, during running each modern ankle joint is abnormally tilted out – away from vertical – by at least **8°** and twisted out – away from straight ahead – by at least **18°** during running midstance while **at peak repetitive loads of three times bodyweight or 3 G's**. Consequently, both legs are misaligned while under this highest normally repetitive bodyweight load that reoccurs during each step in running, particularly the frequent running that occurs during childhood and adolescent growth.

The result of the grossly unnatural misalignment is bilaterally asymmetrical malformation of all of the bone, joint, and other anatomical structures of the modern human body – from toe to head, even including the brain. There is wide individual variation in the degree of resulting artificially-induced deformity, based on factors like types of footwear used over a lifetime, genetics, sex, and just plain luck relative to accidental injuries.

The incredibly extensive deformity of the modern human body begins in early childhood and increases throughout life, reaching its greatest effect in the elderly. The deformity has the potential to damage any structure or degrade any function of the body and to worsen any disease, creating an abnormally high level of unnecessary pain and suffering over an unnaturally long period. Every year in the U.S. alone, its extraordinarily pervasive effects may cause as many as 900,000 unnatural and untimely deaths, as well as almost $1.3 trillion in avoidable medical costs.

Although that constitutes a public health catastrophe of such extraordinary magnitude as to be unbelievable on its face, unfortunately there is irrefutable proof of its cruel reality that has been provided by unusually reliable new evidence. The proof is based on a revolutionary new gold standard of joint motion measurement, a new method that obsoletes the biomechanical results of all of the relevant prior research on the pronation of the ankle joint complex observed during running.

Those prior results indicated substantial pronation of the subtalar joint in the initial part of the stance phase of running, but are perversely misleading. In fact, the surprising new data indicates clearly that the subtalar joint is on the contrary substantially and continuously supinated throughout the stance phase of running, even at peak load of 3 G's. Although counter-intuitive, the observed pronation is only a compensating reduction in reaction to the much more substantial and constant subtalar supination, which is a direct shoe-heel induced abnormality.

As surprising as is this basic paradigm-shifting scientific data, it went unnoticed in a 2014 running research study that focused on other results exploring an unrelated hypothesis. But by chance that neglected data now provides unusually compelling proof of the artificial coupling of elevated shoe heels and subtalar joint supination. It justifies an extensive level of formal research as soon as possible on its potential anatomical and medical effects, which so far appear to be disastrous in the extreme.

ALTHOUGH NATURALLY STABLE, A MODERN BAREFOOT IS LESS STABLE THAN A "PRIMITIVE" BARE FOOT THAT HAS NEVER WORN MODERN SHOES

The inherent stability of the modern bare foot contrasts dramatically with the unavoidable instability of the same foot when shod in a conventional shoe sole. Nevertheless, the inherent stability of a natural bare foot, one that has never been shod in conventional shoes, is likely to be still better. This probable difference between modern and natural barefoot stability is indicated by solid evidence that the actual anatomical structure of the modern human ankle has been substantially deformed by lifelong use of conventional shoe soles.

The unnatural deformation is caused by a heretofore unknown biomechanical interaction between the common elevated heels of conventional shoe soles and the little known **subtalar joint**, unseen in its very well-hidden location directly underneath the ankle joint, between the ankle and heel bones. Astonishingly, that concealed biomechanical interaction spreads deformation throughout the entire modern human body in such a slow and subtle way throughout the entirety of a lifetime, that it has been mistaken for hundreds of years as normal human anatomical development. Instead, it is a serious artificial deformity present in every modern body, the degree of which depending principally on individual shoe use, genetics, and sex.

As destructive and costly as is the defective stability of conventional shoe soles described in the previous analysis, this second structural problem is far worse and immeasurably more harmful.

Evidence from a new gold standard for 3D measurement in laboratory studies provides firm proof of the biomechanical interaction that elevated shoe heels supinate the foot's subtalar joint. That artificial supination inverts and externally rotates the ankle joint: that is, it tilts outward from vertical and twists the ankle to the outside in the horizonal plane. The unnatural supination occurs throughout the stance phase of running, even at peak load of three times bodyweight, thereby deforming all of the human body above and below it, particularly during childhood, but progressing throughout life.

Elevated shoe heels obviously raise the heel of a wearer's foot, which automatically plantarflexes the wearer's **ankle joint**. In biomechanics, it is settled science that ankle plantarflexion supinates the **subtalar joint**, which is located directly under the ankle joint, between the talus (ankle bone) and calcaneus (heel bone). [See **FIGURE 92**] It therefore follows logically that elevated shoe heels must automatically supinate the subtalar joint.[32]

As simple and obvious as that unavoidable conclusion may seem, it remained overlooked and undiscovered until my recent publications. However, this new, formerly unknown coupling biomechanism formed by the shoe heel and subtalar joint is fundamentally important to develop a new and correct understanding of modern human anatomy.

That oversight was made easier because the dual motion of the subtalar joint and the ankle joint has been impossible to measure accurately in the past, particularly during running. During running, those joints are subject to three times bodyweight, the highest repetitive loads the human body experiences. Under Wolff's and Davis's Laws, those peak loads have the capability to gradually remodel the bones and ligaments of joints during each of the millions of running strides that occur in critical growth years of childhood and adolescence.

Now, however, for the first time, truly accurate measurements of the subtalar and ankle joints during running have been made in a study by Peltz et al., funded and directed by Nike, that used the new gold measurement standard based on 3D radiographic and CT scan-based computer modeling.[33] The far more accurate results provided by the new measurement standard clearly indicate that the empirical results of all prior running research studies showing ankle and subtalar pronation were so inaccurate that they were perversely misleading. They mistook substantial pronation for a naturally occurring biomechanism, when in fact it is an abnormal reaction to an entirely overlooked artificial biomechanism, much more substantial supination artificially induced by shoe heels.

Included in the Peltz data is irrefutable proof of the astonishing opposite of a long-standing scientific paradigm that pronation of the subtalar joint and eversion of the ankle joint predominate during running midstance, especially at peak load. Instead, both subtalar and ankle joints were found to be substantially supinated throughout the midstance phase during running, with an extraordinary average combined total of about **8°** of inversion in the frontal plane and **18°** of external rotation in the horizontal plane at peak load of **3 G's**. The subtalar joint position contributes an average of about **5°** of the tibial inversion and the ankle joint position contributes about **10°** of tibial external rotation.

In the first half of the Peltz-reported stance phase (which was measured from footstrike to heel-off) there is a reduction in subtalar joint inversion of about **7°** and an increase in tibial inversion at the ankle joint of about **1°**. That is a considerable net reduction of about **6°** inversion of the ankle joint complex, comparing calcaneal motion relative to tibial motion. In the past this motion has been misinterpreted to exclusively be ankle joint eversion or pronation caused mostly by subtalar joint eversion or pronation.

However, the new more accurate Peltz data indicates the polar opposite reality. Although the observed subtalar joint motion is in a pronation and eversion direction, it is actually only a substantial reduction in a more substantial continuous supination and inversion, which remains at least at **5°** of inversion and **8°** of external rotation even at peak load of about three times bodyweight during the stance phase of running.

Moreover, the observed subtalar joint pronation of **7°** is only a reduction from a much more substantial supination of **12°**. The pronation reduction is just an abnormal reaction to only partially compensate for the greater, completely unnatural, shoe-heel induced supination. That pronation abnormality is supported by a great deal of evidence, including that such apparent pronation motion is not observed in the feet or ankles of runners in barefoot populations who have never worn shoes and therefore do not have artificially supinated feet and ankles from elevated shoe heels.

To summarize, the subtalar and ankle joints are artificially supinated by elevated shoe heels, and any pronation motion that occurs is unnatural and occurs only in reaction to the artificial supination, its effect being to reduce the artificial supination. This explanation flatly contradicts the previously known science, but must be now accepted as the correct understanding of the actual biomechanics revealed in the irrefutable Peltz data.

The Peltz study data also indicates that modern barefoot runners show the same subtalar and ankle joint supination at peak load even without elevated shoe heels. That evidence of such a '**preferred movement path'** would be expected, given the extensive permanent changes to all of their bones outlined above. It explains why the barefoot running revolution ignited by the 2009 best seller, "***Born to Run***," was destined to fail, as it did.

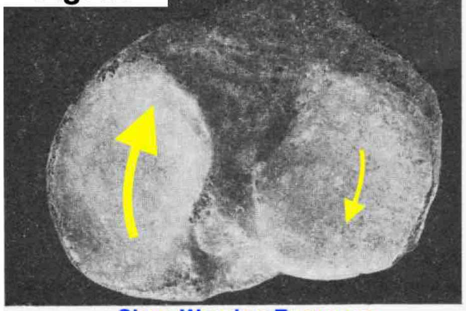
The artificially misaligned talus and tibia – with a large **8°** outward tilt, instead of vertical and larger **18°** outward twist, instead of straight ahead – is virtually certain to have profound effects on the structure of the modern human body that have never been explored until now. During running, that structure is subjected to **3 G's**, the highest repetitive loads the human body experiences. Initial research indicates that the anatomical effects are extensive, as would be expected under the simple and straightforward operation of the well-known and long-established laws of anatomical development of Wolff and Davis.

For example, the trochlear surface of the ankle joint of a **modern habitually shoe-wearing Englishman** has an angled lateral extension and a shorter medial side, together indicating a rotary motion built into the bone structure of the ankle **(FIGURE 93**).

In comparison, an exemplary parallel-sided talus of an **ancient barefoot Anglo-Saxon** has no apparent rotary structure and therefore likely functioned as a stable hinge joint, the primary purpose of the ankle joint **(FIGURE 94)**. The artificial restructuring of the modern ankle joint explains why ankle spraining is the most common sports injury and also the most common cause for hospital emergency room visits.

Similarly, an abnormal rotary torsion – well-known as the unexplained "screw-home mechanism" – is built into the tibial bone structure of the modern knee joint example of a habitually **shod Modern European** (**FIGURE 95**). It gradually enlarges and weakens one or both knees, promoting osteoarthritis, as well as ACL and other knee injuries.

Fig. 95



Shoe-Wearing European

FIG. 96

Barefoot Australian Aborigine

In contrast, the same length shin bone or tibia of the rarely injured natural barefoot knee example (**FIGURE 96**) of a non-shoe wearer, a barefoot **Australian Aborigine**, has a smaller, simpler structure, with no abnormal built-in rotary motion and with stronger, more secure ligament attachments, such as for the iliotibial tract (circled in **red**), as do other, equivalent tibia examples from barefoot Caucasians from India and ancient Rome.

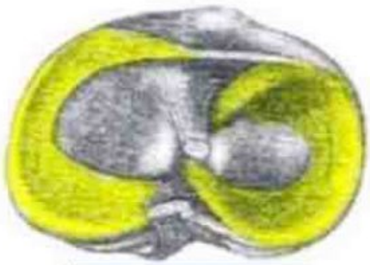


Fig. 96A

Modern Knee Joint

The asymmetrically twisted and malformed menisci highlight the abnormality of the modern knee. The medial meniscus is pushed far forward on the tibial plateau by the femur, the lateral meniscus slightly backward. (**FIGURE 96**A)

In evolutionary terms, it is well-established that the human body was born to run. However, in modern "evolution-in-reverse", an artificial transformation of the human body from natural to deformed has occurred from running with supination-inducing modern shoe heels.

During locomotion, especially running, the supinated subtalar and ankle joints automatically twist and tilt the entire skeletal structure of the bipedal human body into a bilaterally asymmetrical position. This includes both legs, as well as the pelvis, and everything supported by it, including the lumbar, thoracic, and cervical spine, and head.

This deformed prototypical modern human body is unlike a **barefoot African Bushman** who, having grown up always barefoot, has a natural body structure when running in the peak load position in midstance, as shown in **FIGURE 97**: symmetrical with straight legs and level pelvis, with no leg crossover and well-defined spine, as well as no apparent foot supination or pronation. Evidence indicates that Caucasians and Asians who have never worn modern shoes, such as Zola Budd as a teenager and Kim Phuc as a child, have the same straight, vertically aligned body structure as the African.

In contrast, the modern body of a **shoe-wearing Finnish marathoner**, having grown up with modern shoes with elevated heels and resulting supinated feet, is tilted and bent away from a vertical centerline when also shown running in the peak load position in midstance in **FIGURE 98**.

He has a twisted pelvis and bent-out thoracic spine with shallow definition and unnatural torsion abnormally distorting his chest, possibly pressuring the heart and thereby promoting heart disease over time. His thoracic spine is unnaturally tilted-out from alignment with the base of his spine, his center of gravity, so to counterbalance that misalignment his neck and head (both skull and brain) are tilted-in abnormally.

In summary, the prototypical modern human body has been shockingly deformed – artificially by footwear, not predetermined by genetics – resulting in unnaturally exaggerated anatomic differences between genetically diverse human populations and also between male and female sexes. The overwhelming bulk of evidence points to a new and different understanding of what is normal in human anatomy, despite the fact that gross human anatomy is understood to be a completely settled science that has remained mostly unchanged for the past century and a half.

As **FIGURE 98A** demonstrates, the asymmetrical position of the modern cervical vertebrae when running becomes quite evident even when the body remains at rest in a stationary position – bowing out to the right to compensate for the leftward tilt of the thoracic spine. In addition, there appears to be an arterial aneurysm the right side, an abnormality indicating potential for a future stroke due to atherosclerosis. And **FIGURE 98A** is just a typical example taken at random of modern neck structure.

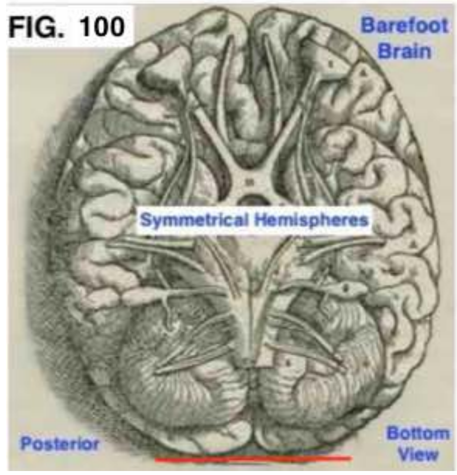
Base on this malformation of the cervical spine, it is remarkably even possible to speculate that ordinary elevated shoe heels have created an unnatural bilateral asymmetry in the modern brain, despite feet and brains being at opposite ends of the human body. Modern neuroscience has firmly established 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 rotation so evident in the asymmetrical structure of the modern brain that it parallels the same unnatural rotation that is evident in the bone structure of the modern knee joint, as previously seen in FIGURE 95, even though the brain is located so far away from the foot and subtalar joint.

The well-known structure of the modern human brain is shown in **FIGURE 99**. The modern human brain is twisted, showing an abnormal built-in structural reaction to unnatural rotary torsion in the shifted positions of the right and left hemispheres, as shown in a bottom view, with the right hemisphere (controlling the body's left side) shifted forward.

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

In contrast to the modern brain shown in FIGURE 99, **FIGURE 100** is a drawing, from 1543 by Andreas Vesalius, which shows a bottom view of a pre-modern, natural brain that developed before the general use of elevated shoe heels. Unlike the modern human brain, Vesalius' drawing shows a natural barefoot brain with symmetrical hemispheres with no major shifting or rotary torsion, just a tiny shift forward of the opposite <u>left</u> hemisphere instead of the right. Other early brain drawings by Christopher Wren in 1664 and A.L.F. Foville in 1844 (from brains that likely developed without elevated shoe heel use) show similarly symmetrical structures.

FIG. 100



The soft tissue of the modern brain appears to be adversely affected by the abnormal twisting of its hemispheres due to ordinary shoe heels. **Stroke** is characterized by a portion of the brain which has died due to an abnormally reduced blood flow to it. As is evident in **FIGURE 101** which is a CT scan of a stroke patient, the stroke has occurred in a brain with marked asymmetry between the **frontal lobes** of the right and left cerebral hemispheres (shown in green), in which their twisted positions evidence significant clockwise rotary torsion. The frontal lobes control the most complex intellectual processes of the brain.

Moreover, the portion of the brain tissue that has died (shown in a **red-orange** color on the left side of FIGURE 101) is in the right hemisphere that has been pushed forward and compressed, probably subject to higher than normal pressure from abnormal clockwise torsion on a repetitive basis. The width of the affected right hemisphere is less than that of the unaffected left hemisphere, again suggestive of regular exposure to higher than natural compressive forces.

It is highly possible, obviously, that increased relative pressure on any portion of the brain would likely have an adverse effect on the flow of blood, potentially sufficient to induce brain stroke. The higher than natural compressive forces that are present in brains with asymmetrical hemispheres would produce that increased relative pressure. It is therefore reasonable to speculate that elevated shoe heels increase the occurrence and severity of brain strokes by increasing brain hemispheric asymmetry, as demonstrated previously.

Artificially twisted brain hemispheres also appear to play a major role in causing chronic traumatic encephalopathy (CTE) caused by repeated concussions (such as in American football). Strong evidence now indicates CTE is likely due to the sudden impact causing extreme brain tissue stretch by up to 50% of its normal volume on the principal network connection between the hemispheres, the corpus callosum (shown in **red** in **FIGURE 102**). As a result, the corpus callosum is likely steadily weakened and deteriorates over time by this repetitive abnormal twisting of the hemispheres under sudden high forces.

The upper cross-section of **FIGURE 103** shows a robust corpus callosum in a normal human brain. In contrast, the lower cross-section shows the severely damaged corpus callosum of a retired NFL football player with CTE. His corpus callosum shows the most deterioration of any portion of his brain.

Other mental diseases, such as dementia, including Alzheimer's Disease and schizophrenia, addiction, anxiety, depression, obsession, multiple sclerosis, and Parkinson's disease, all may be worsened or even caused by the artificial twisting of the modern brain due to ordinary elevated heels.

The cost of the resulting pervasive unnatural deformity in human lives and medical care is so enormous that it must initially seem difficult for anyone to believe. For example, since the deformity obviously makes physical activity more difficult, if not impossible, it probably causes many, if not most, of the **300,000 deaths in the U.S. each year** that the CDC indicates are due to inadequate physical activity,[34] as well as many if not most of the **5.3 million deaths worldwide each year** estimated to be due to physical inactivity.[35]

The artificial deformity is also likely to play a role in initiating or increasing the severity of most diseases, including type 2 diabetes, coronary heart disease, hypertension, osteoporosis, breast cancer, asthma, and liver disease. There is no accurate data whatsoever available at this early stage of investigation, but it is not at all unreasonable to estimate that as many as a third of all deaths that occur in the U.S. each year are primarily due to the profound and pervasive effects of the artificial deformity, the total of which would be more than **900,000 deaths annually**.

Since there is also no available cost data, it is impossible to quantify the medical care costs of the artificial deformity with accuracy. But, again, if only a third of **healthcare** in the U.S. is directly or indirectly caused by the ubiquitous deformity, the associated cost would be about $**1.3 trillion each year**.

Although it is currently impossible to base these cost and death estimates on actual data, they are probably conservative estimates. That is because every part of the modern human body has the potential to be affected adversely and potentially to a substantial degree, with wide variation among individuals, given their vast genetic, lifestyle, and environmental differences, but with the deformity generally increasing steadily with age for everyone.

Although it is obvious that the artificial deformity of the bones, joints, and muscles of the modern human skeleton greatly increase orthopedic costs, it may be much less obvious that other body parts are also directly affected. One example is the case of woman's twisted ankle, injured while tap-dancing, that apparently led to Crohn's Disease, an inflammatory bowel condition, and to spondyloarthropathy arthritis, an inflammation affecting her spine, joints, and organs. After a dozen years of suffering and loss of her teaching job, she was successfully treated by electrical stimulation of her vagus nerve, located at the back of the neck, connecting the brain through right and left branches to the rest of the body.

The twin branches strongly suggest that the valgus nerve may often be adversely affected by the kind of asymmetrical structural deformity created artificially by shoe heels. This is critically important, since the valgus nerve carries signals between the brain and internal organs that regulate digestion, breathing, and heart rate. The brain also controls the immune system through the valgus nerve, so inflammatory conditions like multiple sclerosis, lupus, and Alzheimer's disease may be caused by artificial asymmetrical deformity of the valgus nerve.[35A]

Other examples involve other artificial deformities to the body located even farther away from the foot – the head and the organs contained within it. The artificially twisted and unbalanced head substantially creates or increases disorders of the brain and mental health, mouth and dental, ear, nose, and throat and eye, thereby artificially increasing costs in ophthalmology, dentistry, audiology, neurology, and psychology, for example. All of the human body's soft tissues are at risk of some degree of deformity, which is often substantial (and the resultant malfunction, often severe) due to the unnaturally asymmetrical structural support of the modern human body caused by elevated shoe heels.

Furthermore, to the medical care cost total must be added a **cost estimate of the total work loss** (which would be about 20% of the direct medical cost, using as a basis the CDC estimate methodology used on the cost of falls) or about **$300 billion every year**.

The total estimate of the healthcare and work loss cost of the unnatural deformity in the U.S. alone would therefore be an astonishing $1.6 trillion every year. Moreover, the associated loss in value of statistical life from deaths and loss in quality of life would generate additional trillions to the cost. To put that estimate in perspective, the total annual cost of all healthcare in the U.S. is projected to be about $4 trillion in 2021, which is almost a fifth of U.S gross domestic product, according to data from the Centers of Medicare and Medicaid.

Although this enormous estimate of the total economic cost of the unnatural deformity is shocking, and at least initially beyond belief due to its sheer magnitude, the only available scientific evidence clearly supports the estimate. In addition, the cumulative effect of elevated shoe heels on our general well-being may be even more costly. In the course of each of our lifetimes – but especially as we age – it seems likely that shoe heels drastically degrade our overall quality of life for many years, if not often for many decades, and that cost is beyond accurate measure, but would be in the trillions.

The catastrophic annual cost estimate of $1.6 trillion is simply based on the critical automatic biomechanical interaction between the subtalar joint and elevated shoe heels, and on the anatomical effect of that unnatural biomechanism on the structure and function of the human body due to the inexorable operation of Wolff's and Davis's Laws – both of which are supported and unchallenged by many decades of well-established empirical studies in the formal sciences of anatomy and biomechanics.

In a realistic sense, the shoe is on the other foot in terms of best estimating the true magnitude of the cost of the artificial deformity, since the overlooked critical biomechanism has resulted in a total absence of actual data upon which to base an accurate estimate. Therefore, the real question is, how can those artificial costs not be enormous even if not accurately known now, given the existence of those simple laws and their well-known operation in the human body? Even now at this very early stage, there can be no reasonable doubt that the heretofore unknown deformity has occurred and that it constitutes a major medical catastrophe, whatever may be the exact magnitude of that catastrophe.

In final summary, there really is no way to describe the untenable situation that all of us, as modern shoe-wearers, are trapped in, except to say that we unknowingly have been little more than **human Guinea Pigs** throughout our lives and remain so today. At least for now, we are all inadvertently trapped, involuntarily enrolled in an enormous, unguided experiment in an artificial reverse-evolution that first began for each of us as a fetus in our modern mother's asymmetrically structured womb (unnaturally formed and functioning), then continued when we took our first early childhood steps in conventional shoes with elevated heels, and continues uninterrupted today and into the future.

Each day our bodies become more deformed and farther away from their true natural state. For now, we know virtually nothing about how to stop or even slow that inexorable progression of deformity in all who have worn modern shoes. All we can do now is to prevent the deformity in our youngest children by avoiding the use of elevated heels in their shoes.

How the simple everyday shoe heel manages to create such widespread deformity in every part of the modern human body is the focus of my other new book, titled ***UNNATURAL DEFORMITY: An Unprecedented Medical Catastrophe Hidden In Plain Sight For Centuries***. See the most recent abridged draft and older full drafts in the **Research** section of my website: **www.AnatomicResearch.com**.

August 12, 2022