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APPENDIX – A PERSONAL CRITIQUE OF EXISTING FOOTWEAR

AN INVESTIGATION OF THE PRIMITIVE STATE OF FUNCTIONAL DESIGN IN MODERN ATHLETIC SHOES, WITH MANY EXAMPLES

LEADING BIOMECHANICS SCIENTISTS HAVE LONG AGREED THAT USEFUL SCIENTIFIC RESEARCH ON MODERN ATHLETIC SHOES DOES NOT EXIST

To begin, it should be noted that the design of modern athletic shoes is not based on useful scientific research for the simple reason that such research does not currently exist, as acknowledged by its own leaders. For example, in 2005, one of the foremost leaders in footwear biomechanics, Dr. Martyn Shorten, PhD, concluded that none of the footwear research being published at that time was worth reading, and that there was no meaningful scientific progress on preventing running injuries, despite many decades of work.[36]

Another of its earliest pioneers in footwear biomechanics and now elder statesman, Dr. Benno Nigg, PhD, observed in 2010 that as researchers they had been barking up the wrong tree for the last 30 or so years.[37] Dr. Nigg argued that groupthink had resulted too readily in easily accepted dogma that produced increasing complex but similar footwear without proven benefit.

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

> The fact that we can't answer many really fundamental questions about the functional benefits of shoes, not to mention their potential detrimental properties, ought to be humbling if not humiliating. Instead of responding with emotionally charged polemics … it's an opportunity, if not a clarion call, to start over.[38]

Unfortunately, it is extraordinarily difficult to start over an entire field of scientific research like footwear biomechanics. In my opinion, during the past decade that process has not even begun, nor is there evident consensus on how to do so. Academic research typically works at a glacial speed anyway.

It is plagued with problems like the replication crisis, at least in part because academic research is a "self-accredited cartel with no market pressure", according to Marc Andreessen, who developed the first internet browser and is now among the most successful venture capitalists in Silicon Valley. He believes that 90% of all research is bad.[39]

However, what seems to me to be a healthy first step is to at least acknowledge some of the rather obvious existing problems in footwear sole research and design. So, I will attempt to "start over" here, with some specific examples of dubious existing technology in modern footwear soles, including some of which I have direct knowledge from personal experience.

AN EXAMPLE OF THE PRIMITIVE STATE OF MODERN ATHLETIC FOOTWEAR

The recent history in modern athletic footwear of siped shoe sole technology provides a good example of the surprisingly primitive state of modern athletic footwear despite its outward appearance as "high tech." First, some background. My summary begins with an episode of that history that is personal, since I think it is possible that it began with my disclosure in 1994 of all of my published patents and patent applications, both U.S. and PCT (foreign), including those relating to my siped sole inventions, to Nike R&D staff as part of initial licensing discussions for my patented footwear technology. I also provided them with **my 1993 prototype** with the same sole as that given to Adidas **[FIGURES 4A-E]**, but with a Nike track shoe upper glued onto prototype midsole and outsole **[FIGURE A]** The only difference in the soles is the color.

FIG. A

Unfortunately, my preliminary discussions with Nike were many months behind negotiations at a much higher level with Adidas that had progressed in such a positive manner that I had good reason to expect a successful outcome. My discussions at Adidas were proceeding at the highest level of Adidas USA in Portland, Oregon, whereas my discussion within Nike were at a significantly lower staff level. Moreover, at this early stage Nike was only considering a prototype development contract with me for running shoes, but, nevertheless, Nike's legal staff insisted on exclusive negotiations with them in order to proceed. In other words, I had to stop talking to Adidas just to proceed with negotiations with Nike, even though it was unclear whether they actually had any real interest in my footwear sole invention.

Consequently, I felt that I had no reasonable choice other than to reject its ultimatum, thereby ending any further discussions with Nike. Several months later, at about the end of 1994, I signed an exclusive patent license with Adidas. At a footwear biomechanics symposium in Cologne, Germany, in mid 1995, about a year after my last conversation with him, my Nike contact inquired as to whether it was still a possible to license my patents, but of course I had to indicate to him that it was not. It is just a guess on my part, but I think Nike was reacting to rumors of "barefootwear" development at their chief competitor, Adidas, and may have just wanted to validate the rumors. Soon after, in January 1996, that competition reached a high level.[40]

MY VERTICALLY SIPED SOLE TECHNOLOGY DEVELOPED IN NIKE FREE RUNNING SHOES

Much later, I was surprised to find in 2003 that Nike had developed a vertically siped sole technology into the Nike ***Free*** line of running shoes. My surprise was based on the fact that I had developed essentially the same vertical sipe technology, which was included in my published patents and applications, copies of which were publicly available and were included in a notebook of published patents and patent applications that I had given to Nike in mid 1994.

Actually, I was not especially surprised that Nike seemed to have copied my then public invention. Although my sipe invention was a novel transformation of an old footwear traction technology into a sole flexibility technology, traction sipes were already well-known in the both the footwear and vehicle tire art, so any potential patent protection covering the new technology was inherently weak and difficult to enforce. That fact became increasingly clear to me from 1991 through about 1995 or so, when I was actively prosecuting my sipe patent applications with the U.S. Patent Office.

What I did find almost shocking was that Nike had chosen to commercialize a technology that I personally had thoroughly tested and, as a result, believed to have very limited functional benefit and some potential weaknesses. I had been able in 1989 and 1990 to test extensively many different running shoe prototypes using the siped sole technology because it was very easy to make prototypes with slits in the soles of readily available marathon racing shoes with minimal rubber heel counters and no other relatively rigid upper structures that would otherwise obstruct the effect of siping the sole to make it flexible like the human barefoot sole.

In contrast, shoe soles with rounded sides like the barefoot sole are extremely difficult to prototype without expertise and equipment I did not have until later when I developed my **'93 Prototype**, which required outside professional help. Based on my extensive testing with about a dozen prototypes, all with different siping patterns, ranging from simple to complex, I concluded that the vertical siped-sole technology was not very effective at creating natural, barefoot-like flexibility in a conventional athletic shoe sole.

As a result, in 1990 I quickly pivoted to a much different approach to create barefoot sole-like flexibility, consisting of moving the sipes or slits entirely inside the shoe sole and making them parallel to the wearer's foot sole, rather than perpendicular to it (that is, in roughly a horizontal rather than vertical orientation). In my unavoidably more limited testing of this more inventive concept, the completely internal sipes proved far more natural and effective, but much more difficult to construct, even a decade later with professional footwear prototyping assistance at **i-generator**.

In consequence of that construction difficulty, I later invented an easier way to construct the internal sole sipes. Unfortunately, no one is currently using the internal sipe technology, despite its clear performance superiority and the fact that all of the earlier, original patents on the technology have expired, so that basic internal sipe technology is now in the public domain, available for "free" use (pun intended) by any footwear company.

NIKE BELATEDLY REDISCOVERS OF THE CRITICAL MOTION OF THE BIG TOE DURING RUNNING, OVERLOOKING FAMOUS CENTURY-OLD PHOTOGRAPHIC EVIDENCE

The lack of good patent protection for the vertical siped sole of Nike's **Free** line of running shoes in 2003 must have been apparent to them. Their only U.S. patent that issued at that time just covered sipes in the shoe's upper material, not it sole.

Nike went to considerable lengths at the time to show how they had designed the new **Free** running shoe directly on the natural functioning of the barefoot when running. On Nike's website at the time they showed slow motion video of a barefoot landing on the grass during running. **[FIGURE B]** The accompanying audio commentary marveled over the central role during running of the natural motion of the unrestrained bare foot, with particular emphasis on the toes, especially the bent-up big toe (or hallux) – what seemed to be an important new discovery.

FIG. B

However, the fact is that this apparent discovery of the bent-up position of the big toe landing during running did not have to be based on new scientific data provided by the high-speed motion capture video shot by Nike researchers. On the contrary, the same discovery about the natural motion of the big toe could have been made at any time since 1887, since the same scientific data is obvious in many runners' landing feet in sideview photographs taken by Eadweard Muybridge in his pioneering work on motion photography, republished in 1955 in a Dover edition titled ***The Human Figure in Motion*** (and still widely available, as are many other similar editions of Muybridge's work). **FIGURE C** is one example among many of his similar sideview photographs of runners' feet about to land on the ground during running.

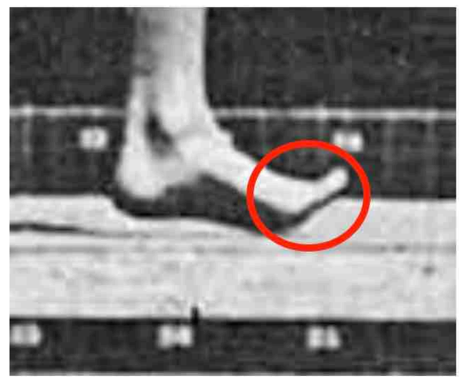

FIG. C

Instead, as this example shows, the natural functioning of the barefoot during locomotion has been ignored in formal research for over a hundred years. As you have seen from my preceding investigation of the instability of conventional shoes compared to the barefoot, formal barefoot research is only at the earliest stage. Neither industry or academic researchers have even the most fundamental knowledge about the unnatural instability of conventional footwear. Worst still, as my investigation has shown, they are not even aware that they do not know it – a case of the infamous unknown unknowns.

THE DESIGN OF SIPES IN NIKE *FREE* RUNNING SHOES DEFIED LOGIC BASED ON ITS NEW-FOUND KNOWLEDGE ABOUT THE BENT-UP BIG TOE

This unusually distinct bent-up motion of the big toe when landing during running was specifically accommodated in the Nike patent and in Nike ***Free*** production models, with sipes in the upper positioned directly over the big toe to allow for its apparently necessary extra freedom of natural motion. Oddly, however, the sipes run across the big toe, which does allow for a little additional unrestricted upward motion, but much less than the more intuitive positioning of upper sipes in line with the big toe. Putting it bluntly, this is a silly design mistake on the only patented feature of the then-new ***Free*** running shoe. [**FIGURE D**]

FIG. D

Making that specific design choice far worse is the fact that the entire forward two/thirds of the ***Free*** model upper is heavily siped, but all of the multitude of other upper sipes are perpendicular to the big toe sipes. And, of course, unlike for the big toe, there is no high-speed video indicating that any other part or all of the running foot evidence upward natural motion that requires upper sipes to allow. In other words, the ***Free*** alignment of the functionally important big toe sipes is worst possible, and all the other many sipes are aligned correctly, but without any particular function, except ventilation.

Unfortunately, this big toe upper sipe is only a glaring example of a much more widespread problem in the basic design of the part of a shoe upper that covers the big toe. The athletic shoe industry has ignored the basic running shoe problem of the locked-down big toe for decades despite recurring evidence from distance runners that seems hard to miss, even without the Muybridge photographs.

FOOTWEAR INDUSTRY-WIDE DESIGN FOR SHOE UPPER OVER THE BIG TOE HAS BEEN COMPLETELY WRONG FOR DECADES

A well-known fact for many decades, ultramarathoners have been forced to cut out the big toe areas of their running shoes. Many marathoners and other distance runners who did not do so have experienced blacked toenails on their big toes, an even more widely known fact. Incomprehensibly, other than ignoring the problem and doing nothing, the standard response of the footwear industry has been to reinforce the area of the running shoe upper around the big toe, obviously in a simple-minded effort to deal with the extra toe wear there, but, as obviously, in complete ignorance of the natural function of the big toe when the foot lands during running. [**FIGURE E**] Ironically, most less expensive shoes omit the reinforcement "enhancement", so you get better function for less by getting less.

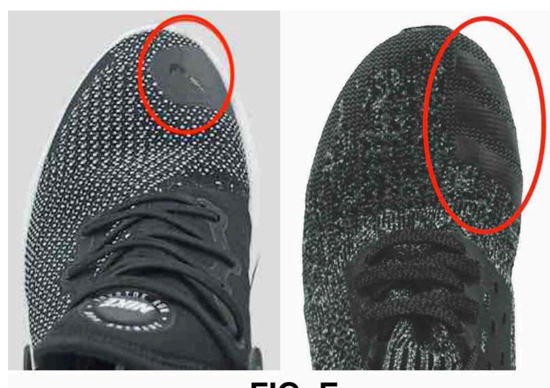

FIG. E

What does seem obvious about the natural function of the big toe to even the fairly casual observer is that it is naturally bent up when landing during running in order to place the main or longitudinal (medial) arch under maximum tension and height, the arch then lowering as the toe lowers in order to make the foot more flexible to effectively absorb the impact shock of it landing on the ground.

This naturally coordinated action of the main arch and big toe is an example during the landing phase of the well-known **windlass effect**, first described by J. H. Hicks in regard to the propulsive phase of the foot during running and walking. During that phase, the heel lifts off the ground, thereby bending the big toe up into the same position as it is in when the foot lands during locomotion, thereby making the foot a more effective rigid lever for propulsion (see **FIGURE 6B** of my **Second Book**).

As will become apparent in my second book, which is on the extraordinary effect of elevated shoe heels to deform the entire modern human body, the same windlass effect plays the central role in a heretofore hidden human anatomical and medical debacle, as summarized in the **Preview of My Second Book**.

AN UNCOMFORTABLE ADMISSION BY THE AUTHOR: ADIDAS *BOOST* IS MUCH MORE FLEXIBLE THAN NIKE *FREE*

In my opinion, as a commercial product, Nike's ***Free*** line of shoes and the many copies made by other shoe companies the use the vertically siped sole technology have all been made obsolete by a breakthrough in the chemical processing of thermoplastic polyurethane (TPU) by the German chemical company BASF. My understanding is that BASF took their new material to Adidas and suggested it might be useful as a superior midsole material, which Adidas in collaboration with BASF then used to create its "***Boost***" and "***Ultraboost***" lines of athletic shoes, first introduced in 2013.

The result of their collaboration is Adidas ***Boost*** shoes with sole flexibility that is <u>far superior</u> to that of Nike's line of ***Free*** shoes, which use the material **EVA** (ethylene vinyl-acetate), which in many variations has been for many decades the existing midsole material standard in performance athletic shoes. ***Boost*** is also very bouncy, an important "energy return" characteristic and very comfortable, with a feel to me that is a little like memory foam in terms of "give".

The principle difference between the two materials used is the relative hardness of the plastic foam. ***Boost*** TPU can only be made relatively soft (initially around 35 durometers on the Asker C scale of material hardness but now about 45 durometers), in contrast to the much harder 70 durometers used typically used in ***Free*** EVA and most other athletic shoes. (Although the Asker C Scale is a hardness/softness scale, it also seems to correlate almost directly with rigidity/flexibility, for which there is no separate scale.)

Another significant difference may be durability. Many of the latest running shoes use forms of EVA in lower durometers, such as 45-50, in thick soles, but at least some appear prone to significant damage from blunt trauma resulting in serious shredding of material separated from the side.

I confess it pains me to have to say all that, given that I had to endure a multiyear lawsuit in which I was personally sued by Adidas, a multi-billion-dollar international mega-corporation. When the litigation finally ended in 2003, both parties left the relationship with no plans whatsoever for any future relationship, to put it as charitably as possible. I certainly have no relationship with Adidas now nor do I expect one in the future.

Despite that, I have to admit that, with a major assist from BASF, Adidas indeed has a great sole material product in ***Boost*** (TPU), with very good Energy Return (78%) in addition to its flexibility. I was surprised that Adidas seemed to take a long time to recognize sufficiently the material's great value and use it widely across its line of footwear, instead of just in a few running shoes. Now Saucony, Mizuno, and Puma are also using various forms of TPU in running shoe soles, so apparently use of TPU midsole material is generic, not legally limited to Adidas and BASF.

The downside of TPU or ETPU is that it is relatively heavy compared to some newer materials. That extra weight is currently limiting its use, particularly in lightweight running shoes, and particularly in distance racing shoes, which will be analyzed later in this Appendix.

BOOST IS THE BEST CURRENT MATERIAL AVAILABLE FOR ROUNDED SOLES LIKE THE ARIG SLIDE THAT MEET THE NEW ANKLE SPRAIN SIMULATION TEST

Moreover, it causes me much greater pain to point out that, given its exceptional flexibility, ***Boost*** would seem to be an excellent midsole material to use to manufacture the rounded footwear soles like that of the ***ARIG*** slide which my testing has proven have the capability to pass the new standard **Ankle Sprain Simulation Test**.

In fact, my opinion is that the biggest single functional shortcoming of Adidas' entire ***Feet You Wear*** athletic shoes from 1996 to 2003 was lack of sufficient flexibility of the rounded sides. That relative rigidity causes an unnatural side-to-side rocking effect, like a rocking chair. More flexibility is required for the shoe sole to flatten under bodyweight loads like the barefoot to provide natural stability.

Hopefully, the guidance provided by this book and a pair or two of my ***ARIG*** slides will be sufficient for Adidas shoe designers to successfully create their own naturally stable and comfortable footwear specifically using the ***Boost*** midsole material. However, without that new guidance, their recent basketball shoe products seem to indicate that they lacked the expertise to do so.

For example, in 2018 Adidas introduced a new, updated version of the most popular of the original ***Feet You Wear*** basketball shoes, the ***Crazy 8*** **[FIGURE F]** originally worn by Kobe Bryant (as shown in **FIGURE 2**).

The new ***Crazy BYW (Boost You Wear)*** **[FIGURE G]** basketball shoe makes copious use of ***Boost*** in extensively rounded sides, but the **Ankle Sprain Simulation Test** indicates the sole is not laterally stable in extreme supination.

FIG. F

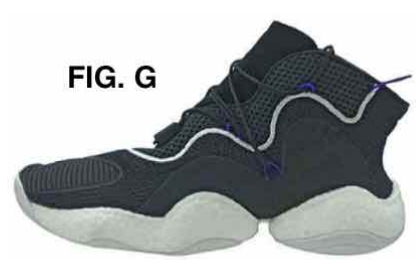

FIG. G

Moreover, I found it also to be extremely uncomfortable, even to walk in. The sole structure was source of the problem.

Adidas moved on to newer models, the ***Crazy BYW 2.0*** **[FIGURE H]**, which is still laterally unstable in extreme supination but much more comfortable, and ***Crazy BYW III***, also unstable in extreme supination. Its sole also includes an extensive plastic network in the midsole making it extremely stiff. **[FIGURE I]**

FIG. H

FIG. I

NIKE GOES IN THE OPPOSITE DESIGN DIRECTION: LIGHTWEIGHT SOLE MATERIAL BUT THICK AND RIGID WITH A REINFORCED CARBON-FIBER PLATE

Beginning with its ***Zoom Vaporfly***, a specialized distance race running shoe **[FIGURE J]** introduced in 2017, Nike has gone in the opposite direction from Adidas, using a much lighter material in much thicker soles in an attempt to maximize energy return. Nike used a midsole material called ***Pebax***, polyether block amide (PEBA), which is modified by Nike and branded as "***ZoomX***", a light and flexible midsole material (about 45 durometers on the Asker C scale).

However, the ***Vaporfly*** sole is highly inflexible because that soft material is used to make a very thick midsole with a full-length carbon fiber plate embedded inside it. The sole is rocker-shaped to compensate for the lack of forefoot flexibility needed during the heel-off to toe-off part of the stance phase of the running stride.

FIG. J

Before proceeding further, I should also point out here that I have no relationship whatsoever with Nike, or any other footwear company for that matter (other than my own research and design company, Anatomic Research, Inc., which has done shoe sole prototyping and limited factory production for development testing and education purposes, with technical assistance from i-generator). All of the views I have articulated in this book are strictly my own personal opinions that have been influenced in no way by a relationship with a footwear company.

POTENTIAL FUNCTIONAL PROBLEMS WITH THE VAPORFLY DESIGN

I believe significant stability problems may be inherent in Nike's approach. First, and most obvious from the preceding stability discussion, the inflexibility of carbon fiber plate embedded in the ***ZoomX*** used in the ***Vaporfly*** series of distance racing shoes together makes it innately unstable as is and functionally incapable of passing the **Standing Ankle Sprain Simulation Test**. The stability of the ***Vaporfly*** and other shoes with very thick and rigid soles cannot be anything close to that of a barefoot, but its basically conventional sole structure can be improved significantly with the addition of the **lateral midfoot sole extension** shown in **FIGURE 88** and a modification of the carbon fiber full length shank as discussed in **Endnote 16**.

As is, the **Vaporfly** sole cannot deform to flatten under a bodyweight load in the way a barefoot does. Moreover, the **Vaporfly** soles are about 50% thicker than conventional running shoe soles, thereby creating larger roll moments paralleling the increase in the effective moment arm, as pointed out by Dr. Wouter Hoogkamer, increasing lateral instability still further than more conventional shoe soles, thereby inviting ankle sprains.[41]

Even worse for lateral stability, the Nike ***ZoomX Invincible*** of 2021 has an amazingly thick heel of over 45 mm, which is about a full 10 mm thicker than typical of the Hoka One One series of running shoes that created the maximal running shoe! I worry that it provides so much cushioning that it pushes front and center the important issue of whether normal bone development is circumvented by the apparent lack of normal impact forces during locomotion. New Balance has a somewhat similar supermax cushioning shoe

The same problem exists with Nike's other running shoes that use ***ZoomX*** alone. In 2020, Nike introduced the ***Infinity React*** running shoe, which is advertised as being specifically designed to reduce chronic running injures. However, it has a wide rocker sole with a relatively rigid ***React*** midsole material, so acute injuries like ankle sprains are likely as unavoidable as in conventional soles.

Second, the rigid curved sole shape of the ***Vaporfly*** sole, particularly with the carbon fiber plate, is designed to reduce the foot's metatarsal joint work, thereby increasing efficiency and speed. There have been a number of similar approaches in past decades, all of which to my knowledge have been abandoned after initially high expectations. Although I have no direct knowledge, I believe the basic problem with this design approach is that it is unnatural and therefore potentially prone to overuse injuries that are not immediately apparent due to the incredible robustness of the human body, which nevertheless eventually breaks down over time.

The Nike-funded published research on the ***Vaporfly*** shoe is strictly limited to efficiency, not overuse or other injuries. Even relative to efficiency, the lead researcher of one of the Nike-funded ***Vaporfly*** studies indicated at a lecture on the ***Vaporfly*** I attended at 2018 Conference of the **American Society of Biomechanics** that the study's researchers were unsure as to how much the carbon fiber plate or the ***ZoomX*** contributed to the experiment's observed efficiency increase. That degree of design uncertainty suggests the running public may be unknowingly participating in a large-scale experiment.

Nike has funded several studies that present evidence of the biomechanical advantages of the ***Vaporfly*** shoe. Unfortunately following industry norms, Nike did not do a published study on the ***Vaporfly*** shoe to evaluate its potential overuse or other injuries, such as those that might become evident when running repeated marathon or other distance races with associated training.

Nor have there been any other published injury studies on the growing Nike ***Vaporfly*** line of shoes or similar shoes now being made by other footwear companies. However, there is anecdotal evidence that such footwear may cause injury problems, which is included in a recent overall research summary of all the issues related to the ***Vaporfly*** and other thick running shoes with carbon fiber plates by Dr. Borja Muniz-Pardos et al. More recently, a formal study indicates bone stress injuries in runners using footwear with a stiff carbon fiber plate. These are typical examples of injury studies undertaken long after the underlying footwear products are made available for public use.[42]

THE EFFICIENCY INCREASE OF THE NIKE ZOOM VAPORFLY IS MUCH SMALLER THAN THE CLAIMED 4% AND PROBABLY DUE TO THE PLACEBO EFFECT

Third, to the extent that the light weight ***Pebax*** material used by Nike reduces the overall weight of the ***Vaporfly*** sole somewhat, some energy efficiency increase would be expected. However, the observable efficiency increase in marathon world records is far lower than the increase of **4.2%** claimed by Nike-funded laboratory research. Moreover, a strong case can be made that even that significantly lower increase is just further proof of the well-proven placebo effect, not the purported increase in energy efficiency of the ***Vaporfly*** sole.

A little running shoe history is in order here first. In 1980, a study by Dr. E.C. Frederick and others indicated that the first Nike air sole shoe, the ***Tailwind***, was almost **3%** more efficient than conventional shoe soles. Of course, as a pioneering first production air sole attempt, the Tailwind had a number of design and manufacturing issues that needed to be fixed over several more years of development, so it was not unexpected that it would take a few years to produce commercial products with such high efficiency.

However, over time, I became increasingly skeptical that air soles were more efficient in the real world. I noticed that year after year Nike's racing shoes continued to use conventional plastic foam instead of air soles. If there was a real efficiency increase from their use, Nike racing shoes would obviously incorporate the air sole technology, in the same way that improvements in car technology generally move from the racing circuit to consumer vehicles.

Fast forward to today and there is a very similar performance claim for new Nike shoes midsole material, which this time were introduced in racing shoes, a big change from the 1980's. However, the actual race performance increases are much lower than the laboratory-based **4%** increases in **running economy** in more reliable, real-world data, which is comparative marathon world record times. Wearing ***Vaporflys***, Eliud Kipchoage lowered the men's record by **1:18** from the previous record of 2:02:57 (also set by a Kenyan at a Berlin Marathon), only by a much less impressive **1%** decrease, not **4%**.

Moreover, Eliud Kipchoage is considered by a considerable margin to be the best ever marathoner in the world, of whom a 1% improvement in the world record should rightly be expected, even in the very highly competitive field of male world class marathoners. His record of past winning performances in major marathons is unprecedented. In his career he has entered eight major marathons in London, Berlin, and Chicago, as well as the Rio Olympics, and won every one, except his first, the Berlin marathon in 2013, where he placed 2nd. This exceptional performance was all achieved before he ever wore a pair of ***Vaporflys***.

Also wearing ***Vaporflys***, Briget Kosgei lowered the Paula Radcliffe's women's mixed sex marathon record of 2:15:25 by almost an identical reduction – **1:21** – 2:14:04 on October 13, 2019. Briget's record also has been attributed to her ***Vaporflys***, but actually it is even more unimpressive than Kipchoage's, since it took 16 years and 6 months to break Radcliffe's record. For comparison Radcliffe beat her own mixed sex marathon world record of 2:17:18 on April 13, 2003 in just 6 months by a greater reduction of **1:53**. So Radcliffe's record was a 32% greater reduction achieved in 33 times less time!

How can that be possible? If Kosgei's record is indicative of a clear performance advantage of ***Vaporflys***, then Radcliffe's record would seem to provide strong evidence that she must have been using a magical technology, perhaps a levitation-enabling shoe sole made of **flubber**.

But Radcliffe's astonishing performance was nothing compared to that of Joan Benoit, who lowered Grete Waite's world marathon record by a much larger **2:46** (more than twice the reduction achieved by Kosgei) and did it an astonishing **one day** after Waite's record was set. If we were to apply the same scale of performance analysis as that used on the ***Vaporfly***, Benoit's record could only have been enabled through the use of a ***Star Trek*** **teleporter**!

DID SUPER-DRAFTING INSTEAD OF THE *VAPORFLY* RACING SHOE BREAK THE TW0-HOUR MARATHON BARRIER

The performance analysis problems do not end there. Drafting behind other world-class runners is a major efficiency advantage in marathon racing, as was proven again by Eliud Kipchoage during his solo race in Nike's unofficial program to beat the two-hour barrier in the marathon. He was protected from both air drag and wind by a large, laser-guided phalanx of seven world class runners surrounding him during the whole race, with fresh substitute phalanx runners to enable the phalanx keep up with the record two-hour pace.

By means of this unprecedented and extraordinarily elaborate drafting advantage, a performance enhancer that has been carefully researched in formal biomechanical studies by Nike researchers, Kipchoage managed to run the distance of a marathon in 1:59:40. He beat his own official world marathon record by **1.6%** (and then reportedly limped off the special motor-racing track).

However, the best available real-world estimate of the performance advantage of the Nike drafting phalanx is provided by a comparison of women's world marathon records, which in recent years have been divided between female-only marathons and mixed sex marathons. The reason for the change to female-only marathons is that, in a mixed sex marathon, elite female racers can draft behind fast male racers during the entire race, whereas in a female-only marathon drafting is difficult for the leaders, so its use is occasional at best, since rabbit runners fast enough to keep a record pace have to quit well before the end of races. Thus, the extra advantage females have in mixed marathons is canceled out in female-only marathons, so that the "playing field" is leveled out for both sexes.

For a direct comparison of this difference, Paula Radcliffe's mixed sex marathon record of 2:15:25 in 2003 is **2:17** faster than her female-only marathon record of 2:17:42 in 2005, providing an indication that the real-world estimate of the drafting advantage is probably about **2:00**. That two-minute advantage would indicate that Kipchoage's epoch 1:59:40 marathon – ironically a **1:59** reduction from his world record – was probably due entirely to the drafting advantage provide by Nike's always fresh drafting phalanx of world class runners, not to his ***Vaporflys***.

Two recent biomechanical research studies provide further support. The first by Polidori et al. reported an estimated 1.91-2.84% reduction based on an evaluation of world-class marathoner Kenenisa Bekele during the 2019 Berlin marathon.[43] The second by Schickhofer and Hanson reported improvements in running economy of up to 3.5% for the best drafting formation, translating to a marathon reduction of 2:36.[44] It should be noted that the first study reported no conflicts of interest, but the second study included an Adidas researcher.

In conclusion, it is entirely possible, if not highly likely, that all of the ***Vaporfly***'s purported real world increases in racing efficiency are due exclusively to the placebo effect. It may well be that, since virtually every runner wearing ***Vaporflys*** believes in the well-publicized **4%** efficiency increase, that belief makes it so, although at a much lower level than expected. Just another proof of the well-established placebo effect.

ONLY DOUBLE-BLINDING CAN ELIMINATE THE PLACEBO EFFECT, BUT WAS NOT DONE IN ANY OF THE VAPORFLY STUDIES

By the way, the only way to eliminate the placebo effect from research studies is to double-blind them, a standard research practice especially common in medical studies to protect human test subjects. However, double-blinding is not done in running studies, for the obvious reason that the test subject runners cannot put on their test shoes and run while blinded, so they see the shoes they are wearing while being tested.

In the specific study that found a lower energy cost of **4%** on average for the prototype of the ***Zoom Vaporfly*** [45] double-blinding was impossible, because the 18 highly elite runners serving as test subjects all certainly would have recognized the two other test shoes, the Nike ***Zoom Streak 6*** and the adidas ***Adizero Adios BOOST*** 2 because they were the two most popular distance racing shoes among highly elite runners at the time of the study. In contrast, none of them would ever have seen the ***Vaporfly*** prototype before, and it looks, feels, and functions in a manner distinctly different from conventional shoe soles.

All 18 test subjects therefore certainly knew that the ***Vaporfly*** prototype was the special new shoe for which the study they were participating in was being conducted. That alters their expectations, which likely affect the test results, reducing or eliminating the validity of those results by introducing a significant potential for a placebo effect. Added to the omission of test subject-blinding, the researchers conducting the study were also not blinded, so their expectations also may have inadvertently colored the results.

Besides this serious placebo effect problem, the 4% research study also disclosed an obvious potential conflict of interest problem, since the study was Nike-funded and 2 of the 5 researchers were Nike employees and the 5th, the senior researcher, was a Nike consultant. Other follow-on research studies, some conducted by Nike and others independent,[56] all lack double-blinding, which must apply both to test subjects and to the research staff conducting the lab test to eliminate the placebo effect.

Finally, none of the supposedly hard biomechanical data included in the study results that showed differences between the ***Vaporfly*** and the other shoes – running economy, as well as stride length, plantar flexion velocity and center of mass vertical oscillation – can be assumed correctly to be immune from influence by the placebo effect on the runners.

OTHER STUDIES ON THE *VAPORFLY* RACING SHOE

It has been reported that less elite runners are able to increase their personal best distance running times by more than the most elite world-class marathoners, but the available data is much less reliable. As reported by ***Runner's World*** (Issue 1, 2020), very large-scale study of "messy" public data like Strava conducted by the ***New York Times*** Upshot, which examined about half a million marathon times, found only a 1% faster time for the Vaporfly than the next fastest shoe (the Nike Zoom Streak that uses neither ***ZoomX*** (Pebax) nor carbon plate). Again, that slightly faster time may have been due to the placebo effect in the ***Vaporfly*** runners.

A ***New York Times*** Upshot study found that the ***Vaporfly*** was 3-4% faster than most other shoes, but an unknown portion of those 500,000 marathon runners ran in accordance with the common practice in marathon running of wearing relatively heavy training shoes to race in in order to avoid injury, probably as many as a majority of the runners. The large-scale Upshot study therefore generally seems to indicate rather conclusively that little or no real efficiency increase was demonstrated by the ***Vaporfly*** shoe in real world conditions. Moreover, the enormous media focus on the "magic" ***Vaporfly*** shoes in their distinctive neon color could only have amplified any placebo effect they might be expected to have.

Another, later study also supports the validity of the superior Vaporfly technology, but without eliminating the placebo effect. [47]

The only available reliable test data for which the potential placebo effect has been eliminated is machine-based material testing done by ***Runner's World***, which indicates that Nike's ***ZoomX*** is 8% better in terms of deflection and rebound, a measure of material "energy return," compared to the next best, Adidas' ***Boost***. However, machine-based testing of running shoes was thoroughly discredited in the late 1970's, having misled shoe designers into creating the super-wide sole of the Nike **LD-1000**, which apparently had difficulties sufficient to be abruptly replaced by a conventional width Nike ***LDV*** shoe.

Since 1970's, human runner wear-testing like that done for many years at ***Runner's World*** has replaced machine-based testing that is not directly related to human performance. Moreover, the validity of "energy return" itself as a valid scientific or technical concept has been hotly debated among footwear science experts for many decades with no recognized consensus.

Lacking reliable scientific data that is double-blinded, it is difficult to avoid the conclusion that all of these ***Vaporfly*** shoe studies are, at best, not strong science, and at worst, meaningless and therefore misleading. Given the way many of the Vaporfly-testing research studies have been used directly and indirectly in marketing, especially given Nike's reputation as one of the best marketing company in the world, if not the single best, the issue of potential conflict of interest cannot be simply ignored.

On the other hand, even disregarding the potential conflict of interest, the study researchers themselves were not immune from the placebo effect. For that matter, none of the Nike employees involved in the ***Vaporfly*** project were immune from the placebo effect and all could have believed quite sincerely in an efficiency increase due to its new sole design.

HAS THE VAPORFLY SIMPLY PROVIDED ANOTHER PROOF OF THE PLACEBO EFFECT

The specific issue of the placebo effect of famous performance brand names has been taken up directly in a recent study, ***Performance Brand Placebos***, by Aaron Garvey, Frank Germann and Lisa Bolton,[48] which notes that advertising is used by companies to create brand narratives. One of their study's results was that golfers who thought they have been given a Nike golf club for a putting test are actually able to play better by 20% than those who thought they were given a lessor brand putter or a no-brand putter (although all actually were given the same club).

The Garbey et al. study provides yet another proof of the placebo effect that simply believing makes it so, particularly for Nike products, the professional use of which by a multitude of the greatest sports superstars is well publicized. It is conventional advertising wisdom that most brands try to create special "halo" products. Nike is generally acknowledged as being better at that than any other company.

Interestingly, the Garvey et al. study found that the placebo effect was greatest in those who were lower in preexisting efficacy, like the multitude of weekend marathon runners in the **NYT** Upshot study discussed above, compared to world-record-class marathoners like Eliud Kipchoage and Briget Kosgei. The Garvey study concluded that "the performance brand effect was due to a lowering of task induced anxiety, driven by a heightened state of self-esteem."

That relaxation effect reminds me of a story I read years ago about Jesse Owens, who was able to break a 100-yard sprint record after being told by his track coach to just aim for a 95% effort instead of a maximum, 100% effort. That relaxation principal seems to be received wisdom in elite track racing today. Similarly, "being in the zone" has been suggested to be better integration of conscious and subconscious reflex functions that improves coordination to make achieving personal athletic bests effortless.[49]

WHY FOCUS ON THE *VAPORFLY*?

You might question why I have spent so much time on the ***Vaporfly***, which might seem like too narrow an issue for so much attention. It is not, since it is now perceived to be, correctly or not, the best shoe for racing. So it is very important because virtually all of the running shoe companies are under intense competitive pressure to copy the use of the Vaporfly's carbon-fiber plate and/or its use of lighter, softer, thicker midsole materials like ***Pebax*** for racing and running shoes.

As noted in a recent ***Runner's World*** review of a new racing shoe, "Like just about every other brand, [company X] wanted a shoe with a carbon-fiber plate to earn some cred."[50] The basic design of all of these new shoes is theoretically based on valid research studies, but, again, the studies probably only validate the placebo effect.

More importantly, this widespread adoption of a new and different running shoe design has been done with no injury studies whatsoever, short or long term, despite the fact that commercial running shoes are generally used by a large portion of the population for everyday walking around use, exposing them to unknown risk. Like the risk of ankle sprains and falls. The only certainty known now is the uniquely different design of all of these Vaporfly-like shoes have increased instability because of the increased thickness of the sole, which magnifies their otherwise conventional sole stability defect.

So, the growing use by the public of the growing ***Vaporfly*** series of Nike racing and running shoe models, as well as clones of both types from other athletic shoe companies, is a problem. Most such models will include the carbon fiber plate, which is not designed or tested for walking, despite the fact that walking is the use for which many if not most of the public will use them. Many new non-racing shoe models by many shoe brands also feature rigid sole structures, such as in the outsole, that mimic the structure and function of the Nike carbon fiber plate.

Even without the carbon fiber plate or its mimics, the very firm rocker sole is a very uncertain device for walking around. In this regard, the best-known rocker sole design in the past was by Masai Barefoot Technology (MBT), which was very popular over a decade ago and was widely copied by other brands, but has faded in popularity since, as have its many clones, suggesting the rocker design may not be very good for walking either (and it was not recommended for running a decade ago, but MBT has since developed running shoe designs).[51]

NEVERTHELESS, THE VAPORFLY DESIGN MAY HAVE AN UNPROVEN BENEFIT

Despite the very serious problems in scientific validity noted above, the possibility still should not be rejected out of hand that the unique ***Vaporfly*** sole may indeed incorporate a relatively new feature that might be an unnatural but still functionally useful improvement to running shoe sole design. One potentially useful feature may be the exaggerated rocker sole shape with both the forefoot and heel curved upward, as seen from a side view, made with a relatively rigid midsole material and curved carbon fiber plate embedded in it. The exaggerated rocker sole is even more pronounced in the redesigned second edition of the model in 2021, the ***Vaporfly NEXT%*** **[FIGURE K]**.

Recall that at the end of this book, in the **Preview of My Second Book**, I summarized powerful evidence indicating that the bone and joint structure of the modern human ankle and foot have been deformed from their natural state by the biomechanical interaction of the subtalar joint and elevated shoe heels. It therefore cannot be ruled out that a rocker sole is biomechanically beneficial by compensating for the reduction of natural function in the modern foot and ankle by reducing its required range of joint motion during toe-off in running and walking.

FIG. K

So, an exaggerated sole rocker might possibly provide in effect a workable crutch to compensate for the artificial deformity of the foot and ankle. A later Nike-funded study by most of the same researchers (without the two Nike employees) provides some support for this view, since the significant effects of the ***Vaporfly*** prototype tested were limited to the ankle joint and the foot's metatarsophalangeal (forefoot) joints.[52]

The steep upward curvature of the heel portion of the rocker sole certainly seems like a reasonable structural approach to mitigate directly the worst effects of the exaggerated heel-strike landing during running. The excessive heel strike occurs as a direct consequence of the unnatural downward extension of the shoe soles caused by elevated shoe heels.

However, the logic is far less clear for the upwardly curved forefoot portion of the rocker sole. The inherent downward motion of the forefoot rocker as the runner rolls onto his toes on the thinnest part of the rocker sole would seem unavoidably to reduce toe-off thrust, which would directly reduce running efficiency.

It might seem fanciful, but it is not impossible that the deformed modern human foot and ankle combined with the forefoot portion of the rocker sole is a hybrid design that goes in the same structural direction as the natural evolution of the horse's foot and ankle into its current, highly efficient state. The only remaining ground contacting portion of the original bone structure of the horse's entire foot is the (non-bone) toenail of its big toe, which forms the hoof.

However, that is quite different from modern human anatomy, so count me as highly skeptical for now, but it is not impossible that in a general way the rigid rocker sole might be at least the most optimal sole among those currently in use. In effect, it might function inadvertently as a therapeutic sole or ad hoc orthotic that at least partially compensates for the widespread structural and functional deformity of the modern human foot and ankle, at least for a category of runners, perhaps pronators.

But, instead, however limited, the available evidence points in a different and perhaps more surprising direction. What I have concluded instead is that the carbon fiber plate inadvertently functions as a band-aid fix that only partially compensates for a critical and very basic structural problem caused by the tapering of the modern rocker sole in the forefoot portion of the shoe sole.

THE FOREFOOT TAPER OF MODERN ATHLETIC SHOES IS A SURPRISINGLY SIGNIFICANT PROBLEM

The most classic example of an old school athletic shoe is the Converse ***Chuck Taylor All Star*** basketball sneaker, which originally dates from 1917. It features a very simple structure with firm rubber traction outsole and soft insole, both with constant thickness running throughout the entire sole from heel to forefoot and with an inner soft heel pad; the insole is about 5mm in thickness and the heel pad about 8mm in thickness, with an upward curvature of the forefoot (often called toe spring) of only 16mm, as shown in sagittal plane cross-section of the ***Chuck Taylor All Star*** in **FIGURE K1**.

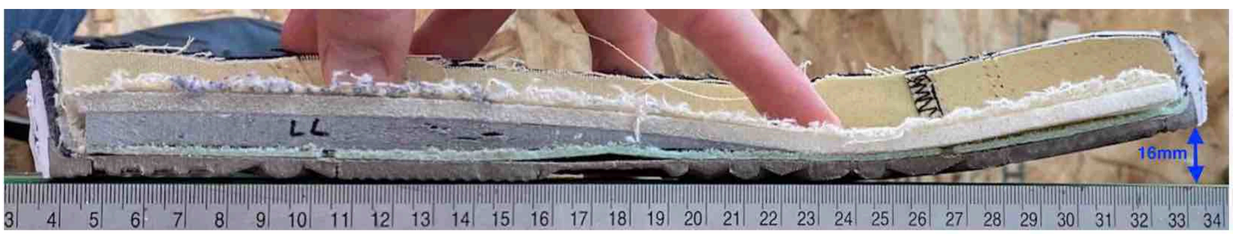

FIG. K1

In short, a very basic, minimalist shoe sole. Besides its lack of substantial cushioning, its main structural deficiency was that it was relatively narrow compared to most modern shoe soles and had a pronounced lateral midfoot indentation, both of which made it structurally conducive to lateral ankle sprains.

But despite that particular shortcoming and their relative lack of comfort, the level of serious injuries of NBA stars was much lower than today during the heyday of the ***Chuck Taylor All Star***. Compared to the NBA playoffs of recent years, which may have reached a terrible peak in 2021, far fewer players suffered serious injuries while wearing ***Chuck Taylor All Stars***.

Introduced to elite NBA players in 1969, the Adidas ***Superstar*** quickly took over from the Converse ***All Star*** as the most popular basketball shoe for professional and college players. It has a nearly flat toe section, although there is a slight tapering thickness from about 3mm to 1mm, and a large heel lift or offset of 13 mm, with an upward curvature of the forefoot (or toe spring) of only 12 mm, as shown in sagittal plane cross-section of the ***Superstar*** in **FIGURE K2**.

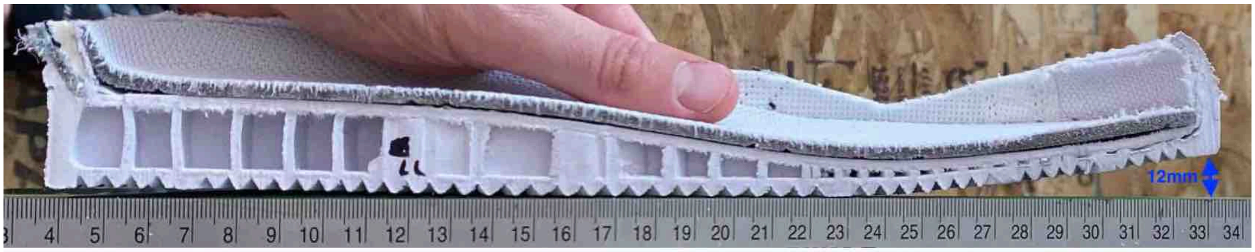

FIG. K2

Even into the 1970's and 1980's, athletic shoes like the Reebok ***Princess*** aerobic shoe and the Adidas ***Marathon*** racing shoe retained the same uniform thickness in the forefoot, despite the introduction of the modern midsole with integrated heel lift or offset.

But this changed. Very thick soles were developed for athletic shoes to provide enough extra cushioning for running on paved roads (I can testify from personal experience that Converse ***All Stars*** were not good for such road running). The most classic example of those I think would be the famous Nike ***Cortez***, introduced in 1972. It includes a tapered portion of the midsole in the forefoot that is essentially limited to the empty space of the toe thrust area. In itself, that midsole taper was not much of a problem, but it and similar forefoot taper in other running shoe soles marked the beginning of a trend of increasing that midsole tapering into the forefoot area under a wearer's toes.

The trend in forefoot midsole taper in athletic shoes has grown for decades and now has reached a forefoot midsole structure close to its practical limit in the ***Vaporfly NEXT%*** shown previously in **FIGURE K** and here in **FIGURE K3**. The extreme taper means that in practical terms there is essentially no midsole material under the wearer's toes at the tip during toe-off but about 30 mm (over 1 inch) of midsole material under the wearer's metatarsal heads, as shown in the side view of the ***Vaporfly NEXT%*** in **FIGURE K3**. It has an upward tilt of the forefoot (or toe spring) of 55 mm, an extraordinary four and a half times as great as the old ***Superstar***.

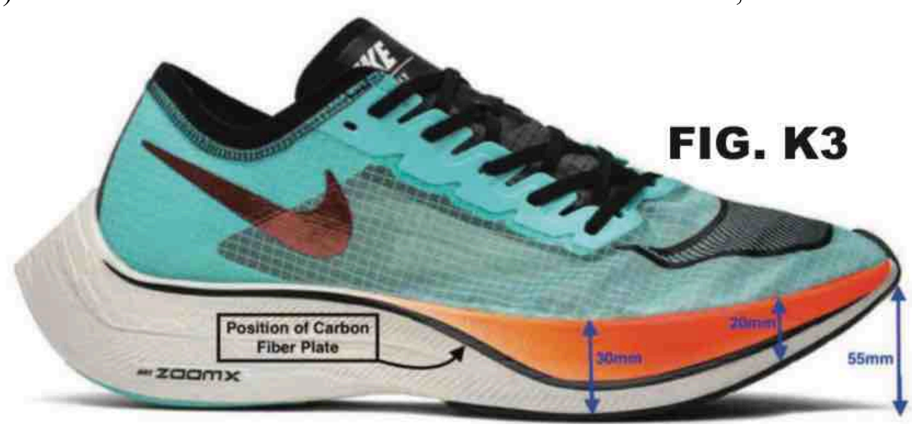

FIG. K3

The problem with that upward sloping structure is that it completely obstructs the natural **windlass effect** that occurs during the toe-off propulsion phase of stance when running or walking. The upper surface of the forefoot of the ***Vaporfly NEXT%*** sole is tilted up, from 30 mm under the metatarsal heads to 55 mm at the tip, an increase of 25mm. The rigid carbon fiber plate keeps the shoe sole forefoot in that tilted up position throughout stance, so the wearer's foot remains tilted up in a semi-rigid supinated position throughout stance, instead of only during landing and toe-off.

The locked-in upward bend of the toes means that the windlass effect is neutralized despite its natural function of causing the foot to become a rigid lever only during the first and last stages of stance when running or walking. During the landing phase, the bare foot naturally changes from a toes-up position to absorb shock to a toes-flat on the ground to provide flexible support during midstance and again to a toes-up position during toe-off to efficiently propel the wearer forward with a rigid foot. So, that natural function of the windlass effect is completely gone.

Without that windlass-induced rigidity, the foot itself cannot be a naturally efficient propulsive lever. Whether intentionally or not is unclear, but the ***Vaporfly***'s rigid carbon fiber plate functions de facto to replace natural, phased foot rigidity governed by the windlass effect with artificially unceasing rigidity that is structurally maintained by the carbon fiber plate. In effect, the plate is an artificial crutch that replaces the missing natural windlass lever-action.

Ironically, then, the wearer's foot is thereby being maintained in the same artificially supinated position that is continually induced throughout stance by elevated shoe heels, as described in detail in my second book, titled "***Unnatural Misalignment***." In other words, the elevated shoe heel artificially supinates the wearer's foot and the rigid carbon fiber plate of the ***Vaporfly*** artificially supports the wearer's foot in that unnatural supinated position.

And in the prototypical ***Vaporfly*** design, the artificial rigidity of the wearer's foot is greatly cushioned with the unconventionally thick and soft midsole. That compensates for the fact that the wearer's foot no longer becomes soft and flexible with toes-flat during midstance, when the typical maximal bodyweight load of three times bodyweight occurs. It is theoretically possible but unproven that this part of the general ***Vaporfly*** design is generally the most optimal approach known currently for compensating for the modern shoe wearer's foot deformed by elevated shoe heels.

Anyway, currently this is only a theoretical discussion. Who knows what the true net efficiency effect of the rigid plate is compared to similarly thick marathon racing shoes without the plate, since to my knowledge none exist today. This might be the best approach and is supported by comments of elite runners on the existing ***Vaporfly*** series of racing shoes. Retaining the very thick midsole layer of soft, high rebound Pebax, which seems to be the acknowledged primary virtue of the ***Vaporfly*** series, is supported by the recovery benefits noted by Trevor Condi, the most elite runner/wear tester in the ***Runner's World*** shoe evaluation program.[53]

On the other hand, removal of the carbon plate is supported by the recommendation to use the ***Vaporfly*** shoes only for races to avoid foot weakness, a warning made by a former professional runner, coach Jon Green.[54]

In my opinion, the basic design is stilled flawed. I believe the design still needs to be corrected by removing the exaggerated forefoot thickness taper of 30mm of mostly midsole material from the metatarsal heads to the tip of the shoe. The forefoot in the above ***Vaporfly NEXT%*** sole example should be 30 mm thick from the heads of the metatarsals, as shown, but that 30 mm thickness should continue all the way out to the tip of the shoe, not tapered. The wearer's toes should be supported by 30 mm of midsole thickness throughout their length, with any thickness tapering only at the tip of the shoe. In the ***Vaporfly*** example, the toe spring of 25mm could remain.

The general tapering problem exists in almost all modern athletic shoes. Whether for more streamlined appearance or other reasons, the resulting unnaturally flexible foot during the toe-off phase of locomotion is a very serious problem. Despite the extensive copying of the ***Vaporfly***'s rigid plate design that has occurred in racing shoes, most modern athletic shoes do not have such a plate. Consequently, in these shoes with substantial forefoot tapering, it is the unnaturally flexible foot alone that must function as an inefficient semi-flexible lever during the toe-off propulsion phase of stance during locomotion.

The most serious problem of the resulting unnaturally flexible foot is that the absence of the windlass effect in the wearer's foot at toe-off causes the subtalar joint to be easily unlocked instead of being in its normal fully locked supinated state. The result is that, like the subtalar joint, the wearer's leg can then also move inward or outward freely sideways in the frontal plane, allowing it to move into unnatural positions during toe-off propulsion like those shown in **FIGURES 13A, 13B and 43A&B**. Both resulted in ACL injuries to the unnaturally bent-in knees of the wearers of forefoot-tapered modern shoe soles.

Although it is very difficult to simulate this biomechanical mechanism, particularly with less extreme modern athletic shoes, my informal static testing indicates that shoes with extreme toe taper, and even the rigid plate like the ***Vaporfly***, allow the wearer's foot to be unlocked during toe-off, thereby risking ACL or other unnatural injuries due to the potential for unnatural sideways motion in the knee joint. The very narrow toe-off pivot point designed into the tip of the ***Vaporfly NEXT%*** sole further increases its sideways instability at toe-off.

To summarize, although it is clear that far more empirical testing must be done, it seems probable that if the tapered structural design of the forefoot of an athletic shoe obstructs the natural windlass effect of the human foot during toe-off. As a result, the subtalar joint will be artificially unlocked and unstable during toe-off when it needs to be locked and stable. There would then seem to be a high risk of avoidable injury to the resulting unstable knee and hip.

THE NEW NIKE TRACK RACING "SUPER SPIKES" – A REAL BREAKTHROUGH OR THE PLACEBO EFFECT AGAIN?

Like the use of the Nike ***Vaporfly*** road racing shoe to set new world marathon records since 2016, during 2020-2021 the new Nike ***Air Zoom Victory*** track racing spikes was used to set new world records in both 5,000 and 10,000 meter races – three times in the women's 10,000 – and also to break Jim Ryun's 55 year old junior record for the 1500 meter. Does this cluster of new track distance records validate a performance breakthrough in racing shoe design or simply provide further confirmation of the validity of the placebo effect of wearing Nike "super spikes."[55]

A century ago, many big track and field meets attracted a considerable amount of attention by the media and the public, but not anymore. Today, there is a tsunami of attention only every four years for the Olympics, but relatively little during the long interval in between. That is quite unlike marathon racing, for which many important international races occur every year, including those in Boston, New York, London, Tokyo, and Berlin.

So, one obvious possibility is that the cluster of new records is due to world class athletes peaking, first, for the 2020 Tokyo Olympics that did not happen and, second, for the 2021 Tokyo Olympics – an unprecedented multiyear peaking period for track racing. That prolonged peaking supports a placebo effect explanation for the unique cluster of world records set with the ***Air Zoom Victory*** "super spikes," similar to the evidence presented earlier indicates may be the case for the ***Vaporfly*** marathon shoe.

However, as it turned out, the ***Air Zoom Victory*** "super spikes" set no new World Records in track at the 2021 Tokyo Olympics. The only track WR records were in the men and the women 100 meter hurdles, and both were won in spike models from other shoe brands, although it is probable that their designs were similar to those of the Nike ***Air Zoom Victory***.

On the other hand, it cannot be ruled out that the ***Air Zoom Victory*** may incorporate a breakthrough technology, one that is different from the ***Vaporfly***. That may be despite the apparent equivalence of the technologies in the two models, since both models pioneered the use of a racing shoe sole incorporating a full-length carbon fiber plate and a super light, energy-returning foam.

However, there is an important difference between the two, and it is not the obvious conventional difference of a spike plate in the ***Air Zoom Victory*** track shoe that is not present in the ***Vaporfly*** road racing shoe. The decisive difference is the lack of heel lift or elevation (or offset) in the sole of the ***Air Zoom Victory***, whereas the ***Vaporfly*** sole has a conventional lift of 8mm.

So, the ***Air Zoom Victory*** has an essentially flat, or zero drop, shoe sole, like the barefoot condition. In contrast, the ***Vaporfly*** has an elevated heel, which creates the serious biomechanical problem due to the interaction between the elevated heel and the subtalar joint that is the principal focus of my second book.

But, despite having a flat sole, the ***Air Zoom Victory*** is distinctly different from the natural barefoot condition. For it is flat only in terms of the thickness of the sole, not its shape.

The full-length carbon fiber plate embedded in the midsole foam holds the spike sole of the ***Air Zoom Victory*** in a unique curled position, as seen in a side view **[FIGURE L]**. That is true even though the upper surface of the shoe sole

inside the upper (which you obviously cannot seen here) is straighter than the lower surface that you can see.

It is essentially shaped like a shoe last for a shoe with conventional elevated heel, despite the absence of an elevated heel in the track spike **[FIGURE M]**. This unique shape has an important effect. When the ***Air Zoom Victory*** is flat on the ground during peak midstance loading of about 3 G's during running, the sole is not flat. Instead it is curled up as if it had an elevated heel and held in that position by the rigid full length carbon fiber plate.

FIG. M

The distinction is made more obvious by comparing this position with the last for a zero drop shoe that has no heel lift **[FIGURE N]**.

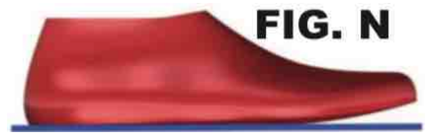

FIG. N

Another distinction that may also be important. The red lasts are shown here are for typical shoes for females, which usually have higher heels than footwear for males. Consequently, the blue last for male shoes is typically are less curled up to compensate for a lower elevated heel **[FIGURE O].**

FIG. O

This later distinction may account for the unusual trifecta of new world records in the women's 10,000 meters during the past year. It may be due to the sole profile of the ***Air Zoom Victory***, which much more closely matches the more curled profile of the typical women's shoe last **[FIGURE M]** than the typical men's less curled last **[FIGURE O]**, which is much flatter.

So, as apparently configured with a typical women's shoe sole shape, the ***Air Zoom Victory*** may provide the best possible trade-off of a natural flat sole that retains the curled shape of the modern human female foot, deformed into a curled shaped by a lifelong use of conventional shoes with elevated heels, again, as described in my second book.

The lack of the curled sole shape created by the ubiquitous modern elevated heel may explain at least in part the lack of sustained success of the barefoot or minimalist running shoe revolution that was sparked a decade ago by Christopher McDougall's 2009 best seller ***Born to Run***. The bare foot is obviously flat on the ground, not curled, and minimalist shoes were generally built using the zero drop last shown in **FIGURE N.**

STUDIES INDICATE THE MORE TECHNOLOGY IN SHOES, THE MORE INJURIES IN RUNNERS

A major difficulty is our lack of knowledge. Research in the footwear industry focuses on increasing performance, not injury avoidance, and therefore there are not many research studies on footwear injuries, whether acute like ankle sprains, or overuse like plantar fasciitis or knee pain. Unfortunately, most runners typically have injury problems. Up to as many as 70% of runners each year get injured from running.

In an injury study in 1989 by Dr. Bernard Marti, a Swiss physician, in a survey of over

4,000 runners.[56] Dr. Marti could find only one variable that correlated with injury, a highly embarrassing one: the price of the running shoes. The more expensive the shoe, the greater was the probability of injury.

Shoe price also usually correlates with the amount of proprietary technology a running shoe company puts in its shoes. The inexpensive ones are plain vanilla, without costly technical bells or whistles. So essentially what Marti found was that the more modern technology the footwear industry put into their shoes, the more likely those shoes would cause running injuries.

It was hard not to conclude generally from these studies that the designers of modern shoe sole do not have a very good idea of what they are doing. Overall, the fundamental structural design of most modern athletic shoes is roughly the same, and essentially not much changed today from the 1970's. With minor variations, the shoe designers just use the same existing basic structural design. Then the designers add whatever new material or great new cushioning or structural technology that they can come up with and use it on the convenient theory, I suppose, that it has to be good since it is new and different.

Unfortunately, it is difficult not to conclude that most of the "improvements" are just contrived gimmicks that all too often backfire by causing unnecessary and unforeseen problems because their only real use anyway is for marketing, not actual performance. (Although, of course, a substantial portion of their profits come from selling classic shoes from the past, without change or presumed improvement, although a relatively recent trend is to substitute new sole cushioning materials into otherwise classic shoes.)

The serious running injury problem has stayed about the same as that which Dr. Marti found in 1989. Recently, in 2015, Jens Jacob Andersen, founder of a Danish Web site called Runrepeat.com, compiled nearly 135,000 consumer reviews and found a similar result: in general, the more expensive the running shoe, the lower the consumer rating.

THE MISSING RUNNING INJURY STUDIES: NONE HAVE EVER LOOKED FOR THE ACTUAL BIOMECHANISMS THAT CAUSE THE WIDESPREAD INJURIES

As useful as the too-rare Marti and Andersen studies are, they did not attempt to investigate the actual injury biomechanisms that cause the increased incidence of injuries. Remarkably, no formal peer-reviewed running studies have ever investigated the actual biomechanisms of running injury; that is, the specific causes and effects, not just observations of correlations. As ludicrous as it may sound, these formal studies only ever test runners who have remained uninjured for a significant period of time and are therefore unlikely to be injured during the study.

Moreover, many moderately injured runners can still run with little or no pain in controlled test conditions. It is reasonable to expect that doing so would be useful in diagnosing the special biomechanical problem underlying the injury, but that never happens either. It follows that there has been no development of important safety tests or basic industry standards for running shoes.

It is difficult not to conclude from the published record that apparently neither the footwear industry nor academic researchers have any real interest in investigating running injuries to find their true causes. I say this having reviewed thousands of running studies over the many decades. Certainly, there have been no important injuries studies that have had tangible impact on the footwear designs of the industry.

Nevertheless, in something of an about-face within the industry, in 2020 Nike introduced a running shoe advertised as specifically designed to help reduce injury, the **React Infinity Run**. **[FIGURE P]** As has always been the case, the features of the shoe that help reduce injury are not identified in advertisements, and there are not published research studies evaluating it that I could find, several structural features of interest caught my eye.

FIG. P

The heel of the sole is almost as wide as the infamous 1970's Nike **LD-1000** running shoe, but the forefoot is actually much wider than that of the **LD-1000.** It is also considerably thicker and rocker-shaped, with the heel is locked-in by a hard-plastic band surrounding the base of the heel counter, a classic "motion-control" device that attempts to hold the heel in an upright position, thereby controlling excessive pronation. Many different motion-control shoes continue to be marketed, but have never had much impact on the unusually high injury rates of runners.

Also, with a 9 mm "offset" or heel lift, the Nike **React Infinity Run** sole design does not attempt to resolve the true underlying cause of excessive pronation during running, which is the heel lift (or elevated heel), the effect of which is the focus of my second book. That book, as summarized in the Preview section at the end of this book, details the severe structural problems caused by elevated heels, but also indicates that zero lift by itself is also a problem, because of permanent anatomical changes to the bones and joints of the modern human body, including the foot and ankle, caused by elevated heels. In effect, the footwear industry inadvertently has blindly painted itself into a corner, with no known way out.

THE MANY DIFFERENT FOOTWEAR CUSHIONING TECHNOLOGIES ARE SELF-CONTRADICTORY

It stands to reason that, if there were a true rational basis for what they do, the major shoe companies would not be marketing several completely different sole cushioning technologies at the same time within the same company, as most of them now currently do. The best-known example is Nike, which at the same time has marketed shoes with sole technologies based on **Air®, Free®, Shox®** **[FIGURE Q]**,

FIG. Q

Vaporfly®, and **Joyride**® **[FIGURE R]**, and many variations with varying sole material combinations and other changes (including, ironically, the Nike **Free RN**, a siped-soled running shoe with Adidas **Feet You Wear**-styled sole bulges) **[FIGURE S]**, and a running shoe like the Vaporfly, with ZoomX midsole material, but without a carbon fiber plate, the **Zoom Pegasus Turbo 2** **[FIGURE T]**. Presumably, if the shoe companies actually knew what they were doing, they would just market the best technology they had (and tell you why, and back it up with valid scientific proof, unlike that provided by the flawed **Vaporfly**-related studies mentioned above).

FIG. R

FIG. S

FIG. T

The actual footwear products seem to suggest strongly that the primary focus of most industry shoe designers is to come up with a cool overall design look for the upper and sole, as well as neat color and pattern combinations. The reality is that virtually all shoe designers come out of an art school background, not science or engineering. Their principal expertise is in making shoes look attractive enough that customers will buy them.

ARE THICKER AND SOFTER MIDSOLES THE MOST OPTIMAL SOLE DESIGN? OR NOT?

I think there are two distinct trends in the past decade in the technology of running shoes, the most popular of athletic shoes. One trend is toward a substantially softer midsole material, first appearing in Adidas ***Boost*** (TPU), which debuted at about 35 Asker C and now at about 45 in ***Ultraboost***, replacing existing midsole material levels of 55-60 Asker C.

The other trend is toward a thicker midsole, pioneered Hoku One One. Greater thickness of soft midsole reinforces the trend toward softness. Both trends together first appeared in the Nike ***Vaporfly*** with a very thick, very soft material, ***ZoomX*** (Pebax), although also with the inflexible carbon fiber shank. The design trend may have reached a practical limit with a heel thickness of 45 mm (or about 1¾ inches) in the Nike ***ZoomX Invincible***.

I believe the apparent effectiveness of this thicker, softer midsole approach rests entirely on its capability to at least partially compensate for the fundamentally wrong geometry of the conventional shoe sole. Its artificial shape is incompatible with, or at least not optimal for, the natural structure and function human foot. The fundamentally wrong shape of shoe soles is just less bad with softer, thicker midsole material.

The basic misconception underlying its conventional geometry is that the shoe sole is essentially shaped like a flat cookie-cutter section of the ground attached to a shoe upper shaped like the wearer's rounded foot sole. Because of its incompatible structure, the shoe sole can never function in parallel with the human foot sole, with its far superior natural stability. A shoe sole cannot retain the foot sole's naturally superior functioning unless it is both shaped like the rounded human foot sole and readily deformable like it.

Unfortunately, softness may not be the simple answer. The extreme midsole softness popular now may well be too soft. If peak impact forces during running are reduced too much, logic would suggest that that would interrupt the normal development of bone structure, resulting in the artificial development of osteoporosis, a serious disease that is particularly prevalent in females.

Equally serious is the potential of excessive midsole softness to increase bilateral asymmetry, which can lead to a multitude of serious injuries. The greater bodyweight load on the dominant side would cause that side to sink lower in the soft midsole relative to the side with the lighter load, increasing the differential in leg lengths and thereby the bilateral asymmetry.

The simple answer may be that there is no simple answer, at least if the basic geometric structure of the shoe sole is incompatible with that of the foot sole.

THE FOOTWEAR INDUSTRY IS FLYING BLIND

A Canadian researcher and physician, Dr. Steven Robbins and a colleague had published a study in 1988 that surveyed the available literature on the injury history of barefoot populations unaffected by modern footwear.[57] What Dr. Robbins found was that those barefoot populations, representing many different racial groupings, had far fewer of the overuse injuries that are widespread in modern shoe-wearing populations.

Even more attention-grabbing was that there were far fewer injuries in barefoot populations and that is despite far higher activity levels on a routine basis, often including what would be called back-breaking work in the modern world. Dr. Robbins' inconvenient data has been ignored by the footwear industry as based on insufficiently valid scientific data, but the footwear industry has not undertaken any studies to correct that alleged insufficiency in the many decades since to refute his data.

Putting it bluntly, that prolonged omission since 1988 might be because his study data strongly suggests that the footwear industry does not know what it is doing. Consequently, new and better scientific proof confirming that longstanding industrywide ignorance would be highly embarrassing for the industry. So, that could be why no new studies have been undertaken during the past three decades.

But, anyway, that has been the known unknown for decades. Now the footwear industry is being blindsided by what for it seems to be what Donald Rumsfeld characterized as the **unknown unknown**. This time, however, no new scientific studies are required to take the problem seriously and act accordingly, so it cannot be conveniently postponed by inaction.

Some kind of reckoning is now unavoidable. Anyone and everyone can easily perform the **Standing Ankle Sprain Simulation Test** to compare their barefoot stability to that of a conventional shoe. After doing so, they cannot avoid asking themselves whether these footwear company guys know what they are doing. The SASS Test makes it obvious to any and all that, without question, they do not.[58]

However, at least for now the footwear industry continues as before, unchanged, essentially an unguided missile. Modern footwear design operates in what is essentially a wild West. There are no established structural laws or even rule-based guidelines of any real consequence. All shoe designs are acceptable for commercial use. As a result, every new footwear design constitutes a new uncontrolled experiment on the public, undertaken without the informed consent normally required in all modern experiments that directly involve human health or safety. In my opinion, based on the simple, easily verifiable evidence I have presented here, those reckless experiments cannot be allowed to continue.

Moreover, my second book provides substantial evidence of a much more profound medical effect on the modern human body of this continuing ignorance of the basic science of footwear sole structure. That ignorance has blindly relegated hundreds of millions of human users to unnatural structural and functional deformity of their bodies, from head to toe.

In addition, in **APPENDIX 2** to my second book, I provide a detailed analysis of the serious scientific deficiencies in fundamental methodology used in current biomechanical research on human locomotion and footwear soles. Unfortunately, footwear science and technology are today at only an embryonic stage of development.

More optimistically, however, they are now poised to take a quantum leap forward, enabled by major advances in digital technology using big data and artificial intelligence, if finally based on a new basic paradigm that is founded on the correct understanding of the structure and function of the natural human body and its artificially-induced modern deformities.

ENDNOTES

1. (p. 2) Based on a R&D report of $130 million expenditure by the Statista website and the Adidas 2020 Annual Report of total net sales of $19,844 million. I could not find any current Nike R&D cost data, even from third parties. As a last resort, when I simply googled "Nike R&D costs", I got nothing of relevance. However, the title of the ninth search result refers to "…Nike's $39B Marketing Strategy", which may be relevant in providing context about Nike's primary focus

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2. (p. 2) **Bajpai**, Prableen (2021). Which Companies Spend the Most in Research and Development (R&D)? **Nasdaq.com**, June 21, 2:30PM EDT.

Some absolute increases in R&D have been enormous in recent years and have coincided with rapid growth. For example, Apple R&D has increased eightfold to $20 billion annually during Tim Cook's tenure, according to ***The Wall Street Journal***, "Apple Struggles in Push to Make Health Big Legacy," June 16, 2021.

3. (p. 3) These statistics are from the **CDC WISQARS, Web-based Injury Statistics Query and Reporting System**: https://www/cdc.gov/injury/wisqars/index.html. Most data shown is from the most recent year, 2022, for which such data is available, and 2021 when later data was not yet available.

4. (p. 4) The estimate of total annual branded athletic footwear sales worldwide in **2022** is about **$94.8 billion**, as reported by ***SPORTING GOODS INTELLIGENCE***, September 8, 2023. The ***SGI*** estimate includes the 25 largest branded athletic footwear companies, which comprise 97.4% of worldwide sales, as well as other branded athletic footwear companies, 2.6%. **Nike**'s share of the total is 32% and **Adidas**' is 16.9%.

5. (p. 5) In contrast to my non-elite running, I was a star basketball player in school, having set single game scoring records twice and a season scoring record, but I must admit that I did peak a little early, in eighth grade.

6. (p. 7) Cover page of U.S. Patent 6,115,945, titled "Shoe Sole Structures With Deformation Sipes:"

US006115945A

United States Patent [19]

Ellis, III

[11] **Patent Number: 6,115,945**

[45] **Date of Patent: *Sep. 12, 2000**

[54] **SHOE SOLE STRUCTURES WITH DEFORMATION SIPES**

[75] Inventor: **Frampton E. Ellis, III**, Arlington, Va.

[73] Assignee: **Anatomic Research, Inc.**, Arlington, Va.

[*] Notice: This patent is subject to a terminal disclaimer.

[21] Appl. No.: **08/162,371**

[22] Filed: **Dec. 3, 1993**

Related U.S. Application Data

[63] Continuation of application No. 07/855,489, Mar. 23, 1992, abandoned, which is a continuation of application No. 07/478,579, Feb. 8, 1990, abandoned.

[51] **Int. Cl.**[7] **A43B 1/10**; A43B 13/14; A43B 13/16

[52] **U.S. Cl.** .... **36/102**; 36/88; 36/103; 36/30 R; 36/25 R; 36/59 R

[58] **Field of Search** .... 36/59 R, 59 C, 36/32 R, 28, 29, 114, 116, 12, 107, 108, 76 R, 102, 88, 103, 30 R, 25 R

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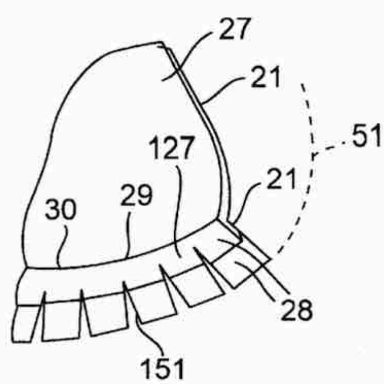
Primary Examiner—Ted Kavanaugh
Attorney, Agent, or Firm—Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P.

[57] **ABSTRACT**

A construction for a shoe, particularly an athletic shoe, which includes a sole that conforms to the natural shape of the foot shoe, including the bottom and the sides, when that foot sole deforms naturally by flattening under load while walking or running in order to provide a stable support base for the foot and ankle. Deformation sipes such as slits or channels are introduced in the shoe sole along its long axis, and other axes, to provide it with flexibility roughly equivalent to that of the foot. The result is a shoe sole that accurately parallels the frontal plane deformation of the foot sole, which creates a stable base that is wide and flat even when tilted sideways in extreme pronation or supination motion. In marked contrast, conventional shoe soles are rigid and become highly unstable when tilted sideways because they are supported only by a thin bottom edge.

9 Claims, 8 Drawing Sheets



7. (p. 11) Peter Moore and his business partner Rob Strasser are famous in the athletic footwear industry for signing Michael Jordan to Nike and also making Nike ***Air*** a major commercial success. That success restored Nike's dominant position in the industry, which it had lost to Reebok in the mid-1980's, due primarily to the runaway success of Reebok's ***Princess*** aerobic shoe at a time when Nike was not focused on the athletic shoe market for women.

Peter's quote is from an Adidas promotional notebook for the launch of the ***Feet You Wear*** footwear in 1996, at a time when he was head of worldwide product development for Adidas. He also had taken over as head of Adidas USA after the sudden death of Rob Strasser. So, Peter had another, even more demanding full-time job at the same time he had to lead the difficult initial development of adidas ***Feet You Wear*** through shoe designers, itself a very challenging task not unlike trying to herd cats. That was obviously not a recipe for success.

Looking back, as it turned out to be just before his death in April, 2022, Peter said

> I think the best idea I have ever seen in footwear is the adidas Feet You Wear concept. It made it to market, but without much support. It created a unique look and feel when it was executed right … which was not very often.

The quote is taken from **Powis**, A. (Ed.) (2021). ***Sneakers Unboxed: Studio to Street***. The Design Museum, p. 80.

8. (p. 11) The "unique" or odd look of the **'93 *Prototype*** was due to the fact that at the time I was designing the prototype I did not know how high the sides needed to go in order to be wide enough to support the essential structural support bones of the foot during extreme pronation and supination. So, I made the prototype sides extra high to make sure they were at least high enough to support the wearer's foot in extreme pronation and supination.

As it turned out, I overdid it, perhaps by more than a little. You may have noticed some white dots on the blue outsole, particularly in the two side views and rear view of my **'93 *Prototype*** (**FIGURES 4B, 4C & 4E)**. To find out how much of the sides were actually ground-contacting during maximum pronation and maximum supination, the dots were added with a felt-tip marker by Dr. Ned Frederick on an ad hoc basis during a preliminary test of the prototype. The dots were added by having a standing wearer rotate the prototype into an extreme supination position for marking and then into an extreme pronation position for marking.

I had intended for the **'93 *Prototype*** to be strictly an engineering test vehicle, not a commercial product, in part because of the odd looking sides that were intentionally extra high. After marketing the ***Key Trainer***, Adidas apparently reached a similar conclusion, and released a revised model based on the ***Key Trainer***, but with much lower sides and other visual details added to refine the look.

9. (p. 11) Other **'93 *Prototype*** 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, as seen in **FIGURES 6G & 6H**, respectively.

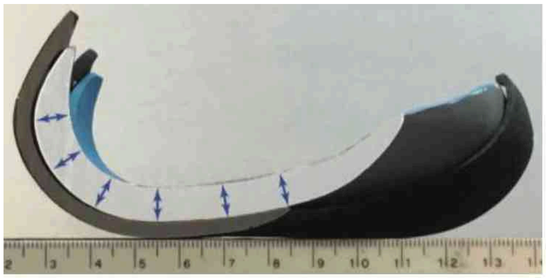


FIG. 6G

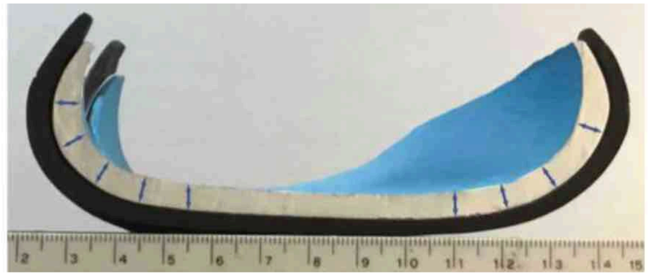


FIG. 6H

10. (p. 11) Other ***Key Trainer*** 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, as seen in **FIGURES 7I-7K**, respectively and **FIGURE 7L**, underneath view.

FIG. 7I

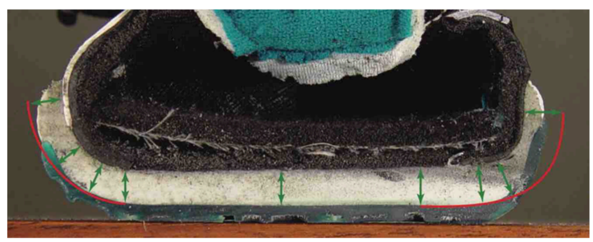


FIG. 7J

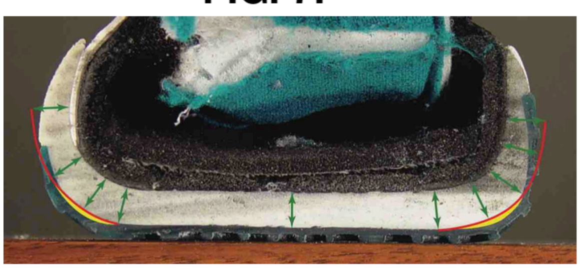


FIG. 7K

FIG. 7L

11. (p. 14) 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, as seen in **FIGURES 7M -7P**, respectively.

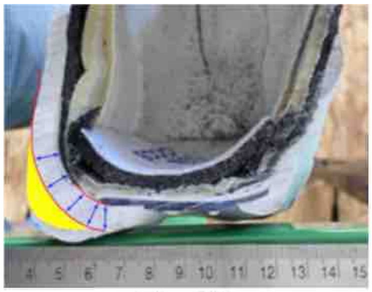


Fig. 7M

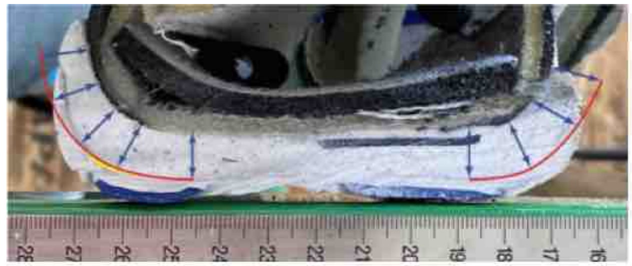


Fig. 7N

Fig. 7O

Fig. 7P

12. (p. 14) Meeuwisse, W., Sellmer, R., and Hagel, B. (2003). Rates and risks of injury during intercollegiate basketball. ***American Journal of Sports Medicine*** 31 (3), 379-385.

13. (p. 15) The expert toy prototype maker was John Nelson, who wrote off all of the significant cost of the failed digital effort, a savings that was crucial to me at the time, since I had little money at the time. After I started to get significant licensing income from Adidas, I repaid John's company with a check for $25,000, an amount that was never billed to me. Further proof that no good dead goes unpunished, when I talked to John several years later I found out that he had been laid off by the company.

14. (p. 16) I cannot ignore the painful irony for me that the two principal structural features of this Nike ***Free*** shoe sole were invented exclusively by me and I am definitely not a world-class runner, nor did Bill Bowerman have any part in its conception or development. The shoe is the Nike ***Free RN 5.0***, a siped-soled running shoe with deep flexibility groves and with Adidas ***Feet You Wear***-style rounded sole bulges (which, however, do not have the natural barefoot stability of my **'93 *Prototype***). The shoe is also described in **APPENDIX 2** and shown there in **FIGURE S.**

14A. (p. 21) Conventional football cleats are substantially more unstable than conventional basketball or other court shoes, as discussed later in detail in an analysis of NFL All-Pro quarterback Alex Smith's life-threatening leg injury relative to FIGURES 87E-87H and 87I-87K.

15. (p. 27) As noted, 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. This is true, despite the fact that the anatomical structure of the modern human ankle bones and ligaments is unnaturally weakened by the second pathogen of the pandemic: elevated shoe heels. See the **POSTSCRIPT** for addition information on this point.

16. (p. 29) **Ritchie**, Stuart (2020). ***Science Fictions***. Metropolitan Books

17. (p. 29) For a detailed case study, there is **The Doctor Who Fooled the World** by Brian Deer (2020), Johns Hopkins University Press, as well as a general study, ***Fraud in the Lab*** by Nicolas Chevassus-au-Louis (Trans. by Nicholas Elliott) (2019), Harvard University Press.

18. (p. 33) My **'93 prototype** shown landing in FIGURE 22 was measured by the university lab's force plate, whereas I measured the conventional shoe later using more informal means without the same test subjects but with reasonable accuracy in a static standing test using a simple bathroom scale to measure the vertical force of body weight (BW). Obviously, since the standing force being measured is essentially static in this test, a force plate is not necessary for accurate measurement.

19. (p. 34) As noted by Garrick, a pioneer in ankle sprain research, "Ideal ankle prophylactic design would not restrict typical joint motions, rather only prevent motions related to ligament damage and injury." **Garrick**, J. & Requa R. (1973). Role of external support in the prevention of ankle sprains. ***American Journal of Sports Medicine*** 5 (5), 200-203.

Real world braces and taping create unnatural problems, since "the use of the lace-up or semi-rigid ankle braces or taping negatively affected agility performance. We feel reasonably confident in our results because ankle braces restrict inversion and eversion ranges of motion." **Ambegaonkar**, J., Redmond C., Winter, C. et al. (2011). Effects of ankle stabilizers on vertical jump, agility, and dynamic balance performance. ***Foot Ankle Spec*** 4 (6): 366-372.

See also: **Forbes**, H., Thrussell, S., Haycock, N., Lohkamp, M., & White, M. (2013). The effect of prophylactic ankle support during simulated soccer activity. ***Journal of Sport Rehabiliation***, Aug 22, 22(3):170-6. **Agres**, A., Chrysanthou, M. & Raffait, P. (2019). The Effect of Ankle Bracing on Kinematics in Simulated Sprain and Drop Landings: A Double=Blind, Placebo-Controlled Study. ***American Journal of Sports Medicine***, May, 47 (6):1480-1487. **Kemler**, E., van de Port, I., Backx, F., & van Dijk, C. (2011). A systemic review on the treatment of acute ankle sprain: brace versus other functional treatment types. ***Sports Medicine***, Mar 1, 41(3):185-97. **Verhagen**, E., van der Beek, A., & van Mechelen, W. (2001). The effect of tape, braces and shoes on ankle range of motion. ***Sports Medicine***, 31(9): 667-77.

20. (p. 37 & 38) **Cohen**, Ben. The Nets Had a Big Three and One Too Many Injuries. ***The Wall Street Journal,*** A14, June 22, 2021.

21. (p. 47) **Nigg**, Benno M. (Ed.) (1986). ***Biomechanics of Running Shoes***, p. 163. Human Kinetics Publishers, Inc., Champaign, Illinois.

22. (p. 48) **Sarrafian**, S. & Kelikian, A. (2011). Functional Anatomy of the Foot and Ankle. In Kelikian, A. (Ed.) ***Sarrafian's Anatomy of the Foot and Ankle*** **(3rd Edition)** (p. 543 & Table 10.5). Lippincott Williams & Wilkins.

The much greater range of supination motion is due to the biomechanical interaction of the subtalar joint and elevated shoe heels over a lifetime of use, which is the focus of my second book (a preview of i is included the end of this book).

23. (p. 51) At this point I feel obligated to offer my take on constructive criticism of Adidas' efforts in the 1990's to develop my barefoot sole based shoe sole technology. Again, these are just my personal views based on the **Feet You Wear** athletic shoes that Adidas produced and I bought to use and test on my own.

First, on a positive note, generally their **Feet You Wear** shoe soles were as **wide as the dynamic footprint**, if not actually wider than they needed to be, as were the most extreme cases of extra width, my **'93 prototype** **[FIGURES 4A-E]** and Adidas' Key Trainer **[FIGURES 5A-E]**. In addition, the wide sides of Adidas **Feet You Wear** shoes also were **rounded**, wrapping up around the curved sides of the wearer's naturally rounded foot sole.

However, I believe the principal shortcoming Adidas **Feet You Wear** shoes was that the soles were **insufficiently flexible** to deform to flatten the way the wearer's rounded foot sole flattens under a bodyweight load. This excessive rigidity or stiffness, typical of conventional shoe soles, creates a rocking chair effect on the rounded sides, so that they are inherently much less stable than the bare foot sole, which creates a wide base of structural support by deforming to flatten.

Also, the barefoot is rounded directly underneath the sole, not just on its sides, so the most natural shoe sole performance requires that structure. Instead, **Feet You Wear** shoes had **flattened areas directly under the foot sole**, with only the sides rounded like a barefoot sole. Moreover, none of the **Feet You Wear** shoes were fully rounded under the heel of the shoe, where it is particularly useful functionally, such as during the landing phase of running to reduce the artificial initial spike in impact force and also in providing optimal lateral stability during extreme supination or pronation to prevent acute injuries like ankle sprains and other injuries.

Finally, and I believe this is the most important point of all, as far as I could tell Adidas staff did not use the **Standing Ankle Sprain Simulation Test** as a fundamental baseline with which to evaluation accurately the stability performance of their **Feet You Wear** shoes throughout all phases of footwear development, from initial design through prototyping to final production, as well as post-production wear-testing in actual game and other real-world stability test conditions.

Again, that is said with my personal opinion is based exclusively on my evaluation of the footwear products alone, without any actual knowledge about Adidas' internal design, production, or testing processes. That is, I can only judge the footwear products that resulted from Adidas' processes, not the internal processes themselves.

24. (p. 62) 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 accuracy, as shown in **FIGURES 85Q & 85R**, respectively.

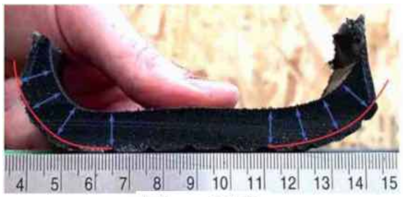


Fig. 85Q

Fig. 85R

24A. (p. 67) **Kelsey**, J., Procter-Gray, E., Nguyen, U., Li, W., Kiel, D. & Hannan, M. (2010). Footwear and falls in the home among older individuals in the MOBILIZE Boston Study. ***Footwear Science***, Vol. 2, No. 3, September, 123-129.

25. (p. 68) In contrast to the CDC-accumulated statistical data on falls, the available data on ankle sprains in the U.S. is spotty, inconsistent, and unconsolidated, available only from a variety of research studies, many from decades ago. A 1961 study characterized the situation then as: "the literature is remarkably lacking in information concerning ankle sprains" (from C. **Ruth**, The Surgical Treatment of Injuries of the Fibular Collateral Ligaments of the Ankle. ***The Journal of Bone and Joint Surgery***, Vol. 43-A, No. 2, March 1961, 229-239). The situation has not changed much since then in terms of consistency and consolidation. Nevertheless, a brief sampling of notable ankle injury research studies is listed below, each of which includes a lengthy list of literature references related to ankle sprains.

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Delahunt, E. … & Hiller, C. (2010). Inclusion Criteria When Investigating Insufficiencies in Chronic Ankle Instability. ***Medicine & Science in Sports & Exercise***, 2106-2121

26. (p. 69) **Arellano**, C. and Kram, R. (2011). The effects of step width and arm swing on energetic cost and lateral balance during running. ***Journal of Biomechanics*** April 29; 44(7):1291-5.

Donelan, M., Shipman, D., Kram, R., & Kau, A. (2004). Mechanical and metabolic requirements for active lateral stabilization in human walking. ***Journal of Biomechanics*** Jun;37(6):827-35.

Kao, A. (1999). Stabilization of Lateral Motion In Passive Dynamic Walking. ***The International Journal of Robotics Research*** Vol 18, Issue 9.

Kao, A. & Donelan, M. (2010). Dynamic Principles of Gait and Their Clinical Implications. ***Sematic Scholar***.

26A. (p. 69) **Hayes**, W.C. et al. (1993). Impact near hip dominates fracture risk in elderly nursing home residents who fall. Calif Tissue Int, 52:192-8. **Parkkari**, J et al. (1999). Majority of hip fractures occur as a result of a fall and impact on the greater trochanter of the femur: a prospective controlled hip fracture study with 206 consecutive patients. ***Calcif Tissue Int***, 65:183-7.

27. (p. 71) Composite **FIGURES 87S-87U:**

FIGS. 87S-87U

28. (p. 76) **Wallis**, C. (2022). When Health Takes a Tumble: Falls among the elderly are a top cause of death. ***Scientific American***, October, 30.

28A. (p. 77) **Blase**, Brian (2020). The Disappointing Affordable Care Act, ***Forbes***, September 23.

29. (p. 83) An issue related to the **midfoot lateral sole extension** is the conventional position of rigid (or semi-rigid) **shank** in conventional shoe soles, whether full length or the more conventional partial length, or **midfoot torsion systems** in athletic shoes that are used to support the midfoot, which is often not ground-contacting, between the forefoot and heel portions of the sole that are ground-contacting.

The shoe sole shank is traditionally located in the center of the midfoot, along the long axis of the sole, probably for the shoe-making convenience of cobblers centuries ago. However, the main longitudinal arch of the foot that connects the heel and forefoot is not just a simple medial arch between heel and forefoot. It has a much stronger and more complex 3D structure that looks schematically like a half of a dome or hemisphere. **[FIGURE 88F]**

Midway between the heel and forefoot is the base of the 5^{th} metatarsal bone, the single bone structure located in the lateral midfoot that supports the main longitudinal arch. The base of the 5^{th} metatarsal bone is located on the edge of a conventional sole at the center of the midfoot, a location that is precisely where the traditional indentation of the conventional sole midfoot is also located. That means the base of the 5^{th} metatarsal bone is poorly supported because of the traditional midfoot indentation of conventional soles.

Since the base of the 5^{th} metatarsal is the key structural support of the main longitudinal arch, the shank should be moved from its traditional central location to a lateral location in order to directly support the base. The **midfoot lateral sole extension** of the midfoot of the conventional sole shown in **FIGURE 88B** also makes the proper relocation of the shank to a lateral position easier to position correctly.

In addition, the **midfoot lateral sole extension** itself can be improved in a limited way to look and function like the rounded sides of my prototype designs, but limited just to the **midfoot lateral sole extension**, so that it is fairly easy to implement. Since the midfoot area is not typically a high wear area, it can be made of midsole material alone, without a more durable outsole.

To uncouple the shoe sole forefoot from torqueing over the heel in the lateral ankle spraining position, it is also useful to create flexibility between the **midfoot lateral sole extension** and the forefoot and heel with deep sipes or relatively soft midsole material, as discussed previously relative to **FIGURE 89**.

30. (p. 85) Both studies are available at anklerollguard.com under Testing & Information. **Ihmels**, W., Seymore, K., & Brown, T. (2020). Effectiveness of Novel Ankle Prophylactic Compared With Lace-Up Brace or Tape. ***Journal of Sport Rehabiliation***, (Jan 2), 29:5, 693-696. **Ihmels**, W., Seymore, K., & Brown, T. (2020). Effect of Sex and Ankle Brace Design on Knee Biomechanics During a Single-Leg Cut. The ***American Journal of Sports Medicine***, 48:6, 1496-1504.

31. (p. 93) What the potential risks are to the footwear industry are described in detail in an interesting new book, "***The Sack of Detroit***" by Kenneth Whyte (2021), Alfred A. Knoph. Mr. Whyte's summarized just one of the serious risks succinctly: "Regulators step in where markets fail, and markets were failing on auto safety." (p. 328) His Prologue and Epilogue provide excellent summaries of the main details.

See also "America's Car Crash" by Barbara Spindel in ***The Wall Street Journal***, May 28, 2021, p. A13. The main take-away from the Detroit auto industry's experience is that it would likely be far better for the footwear industry and its customers to proactively correct the sole stability defect that to be forced to do so by others.

FOOTNOTES TO THE PREVIEW OF MY SECOND BOOK

32. (p. 96) **Ellis**, F. E. (2019). Shoe heels cause the subtalar joint to supinate, inverting the calcaneus and ankle joint. ***Footwear Science*** 11, S176-177.

33. (p. 96) **Peltz**, C. D., Hakadik, J. A., Hoffman, S. E., McDonald, M., Ramo, N. L., Divine, G., Nurse, M. and Bey, M. J. (2014). Effects of footwear on three-dimensional tibiotalar and subtalar joint motion during running. ***Journal of Biomechanics*** 47, 2647-2653, **Figures 4, 5, 7 & 8**.

34. (p. 102) **Carlson**, S. et al. (2018). Percentage of deaths associated with inadequate physical activity in the United States. Prevention of Chronic Disease 15, 170354.

35. (p. 102) **Lee**, I. et al. (2012). Effect of physical inactivity on major non-communicable diseases worldwide: An Analysis of burden of disease and life expectancy, ***Lancet*** 380, 219-29.

35A. (p. 103) **Finley**, A. (2022). Electricity Is the New Medical Miracle. ***The Wall Street Journal***, July 22.

FOOTNOTES TO THE APPENDIX

36. (p. 1) **Shorten**, Martyn (2005). Footwear Biomechanics: What Does the Future Hold? ***The 7th Symposium on Footwear Biomechanics*** of the Technical Group On Footwear Biomechanics of the International Society of Biomechanics.

37. (p. 1) **Nigg**, Benno M. (2010). ***Biomechanics of Sports Shoes***. Calgary, Alberta. [PAGES ?]

38. (p. 1) **Frederick**, Edward C. (2011). Starting Over. In ***Footwear Science*** 3: 2: June, 69-70.

39. (p. 1) Marc **Andreessen** quoted by Andy **Kessler** (2022). 90% of Everything Is …. In ***The Wall Street Journal***, January 24, A17. His incisive article focuses on **Sturgeon's Law**, which states that "90% of everything is crap", which Andreessen notes specifically applies to music, paintings, writing, TV shows, and movies, while Kessler adds ideas, stocks, opinions, and politicians to the list of examples. Andreessen is quoted as saying that Sturgeon's Law reflects:

> …the nature of creative work. There are only a few people in each field that know what to do. …In these domains, we have a very small number of people who know what to do. And we have a much larger number of people typically laboring under some set of delusions – generally crap. It is what it is.
>
> … Super-talented [people leave academia or big companies because they realize they're] swimming in an ocean of mediocrity. …But it's not the fault of the people, it's the fault of the systems.

Based on the analysis by famous venture capitalist Andreessen, Kessler adds that "Academic research and big companies … need a new model. Take note, Apple, Amazon, Facebook and Google."

The provocative article's link is www.wsj.com/articles/90-percent-of-everything-is-crap-venture-capital-marc-andreessen-mosaic-web-silicon-valley-tech-investment-innovation-11642970894?st=pm9zj7rnu2guxr3.

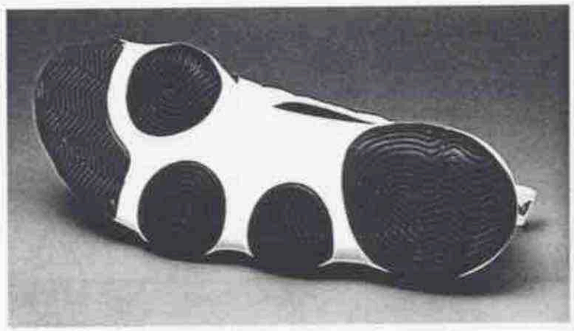
40. (p. 2) **FIGURE U**, from ***SPORTSTYLE***, January, 1996, p. 40.

Technology '96:

Bare vs. Air

Nine years ago, Peter Moore was huddling with a small group of colleagues in Nike's Oregon offices, preparing for the imminent release of the product — Air cushioning — that would shake Nike from its doldrums and change the face of the athletic shoe industry.

Now Moore, ensconced across town from Nike in Adidas' Beaverton, OR, offices, is preparing for the release of a product that he hopes will have something approaching Air's impact: the "bare foot" concept, or what Adidas is, with calculated simplicity, billing as "Feet You Wear."



Adidas: The new technology is like walking in your Bare feet.

Nike: What can be lighter than Air? More Air!

FIG. U

41. (p. 9) **Hoogkamer,** Wouter (2020). More isn't always better, ***Footwear Science***, Vol. 12, **1**-3. See also **Hannigan**, J. J. & Pollard, C.D. (2020). Differences in running biomechanics between a maximal, traditional, and minimal running shoe. ***Journal of Science in Medicine in Sport***, 23(1), 15-19.

42. (p. 10) **Muniz-Pardos**, B., Sutehall, S., Angeloudis, K., Guppy, F., Bosch, A. & Pitsiladis, Y. (2021). Recent improvements in marathon run times are likely technological, not physicological. ***Sports Medicine*** 51:371-378, especially **p. 374** and references **81** & **82**.

43. (p. 12) **Polidori**, G., Legrand, F., Bogard, F., Madaci, F., & Beaumont, F. (2020). Numerical investigation of the impact of Kenenisa Bekele's cooperative drafting strategy on its running power during the 2019 Berlin marathon. ***Journal of Biomechanics***, 107, 109854, 1-8. And **Tenforde**, A., Hoeing, T., Saxena, A. & Hollander, K. (2023). Bone Stress Injuries in Runners Using Carbon Fiber Plate Footwear. ***Sports Medicine*** 53:1499-1505.

44. (p. 12) **Schickhofer**, L. & Hanson, H. (2021). Aerodynamic effects and performance improvements of running in drafting formations. ***Journal of Biomechanics***, 122, 110457.

45. (p. 12) **Hoogkamer,** Wouter; Kipp, Shalaya; Frank, Jesse; Farina, Emily; Luo, Geng; and Kram, Roger (2018). A Comparison of the Energetic Cost of Running in Marathon Racing Shoes. **Sports Medicine,** 48, 1009-1019, particularly **1016-17**.

46. (p. 13) **Hunter**, I., McLeod, A., Valentine, D., Low, T., Ward, J., & Hager, R. (2019). Running economy, mechanics, and marathon racing shoes. ***Journal of Sports Science***, 37 (20): 2367-2373. **Joubert**, D. & Jones, G. (2022). A comparison of running economy across seven highly cushioned racing shoes with carbon-fibre plates. ***Footwear Science***, February 21. **Nigg**, B., Cigoja, S. & Nigg, S. (2020). Effects of running shoe construction on performance in long distance running. ***Footwear Science***, Vol. 12, No. 3, 133-138.

Subramanium, A & Nigg, B. (2021). Exploring the teeter-totter effect in shoes with curved carbon fibre plates. July. **Patoz**, A., Lussiana, T., Breine, & B. Gindre, C. (2022). The Nike Vaporfly 4%: a game changer to improve performance without biomechanical explanation yet. ***Footwear Science***, May 23.

47. (p. 13) **Goss**, C., Greenshields, J., Noble, T. & Chapman (2022). A Narrative Analysis of the Progression in the Top 100 Marathon, Half-Marathon, and 10-km Road Races Times from 2001 to 2019. ***Medicine & Science in Sports & Exercise***. Volume 54, Number 2, February.

48. (p. 14) **Garvey**, A., Germann, F. & Bolton, L. (2016). Performance Brand Placebos: How Brands Improve Performance and Consumers Take the Credit. ***Journal of Consumer Research***, 42 (April) 931-951.

See also Vedantam, S. & Mesler, B. (2021). *Useful Delusions: The Power & Paradox of the Self-Deceiving Brain*, especially pp. 29-58. Norton.

See also book review by Matthew **Hutson**. The Liar in the Mirror. ***The Wall Street Journal***, March 3, 2021, p. A15.

49. (p. 15) Roy **Palmer** quoted in **King**, S. (2006). ***Running in the Zone: A Handbook for Seasoned Athletes***. Trafford Publishing: Victoria, BC Canada, and **Locke**, A. (2001). Being in the Zone: notions of agency in athletic performance. ***Proceedings of the British psychological society***, 9 (1), p. 83.

50. (p. 15) ***Runner's World***, Issue 2, 2021. p. 57.

51. (p. 15) I feel compelled to note also that the MBT website list 9 research studies supporting its benefits, 8 of which highlight its instability in the study titles. Given all the evidence of barefoot stability I have presented in this book, the use of the word "barefoot" or "Masai barefoot" in the MBT brand name is difficult to understand on a functional basis.

52. (p. 16) **Hoogkamer,** Wouter; Kipp, Shalaya; and Kram, Roger (2019). The Biomechanics of Competitive Male Runners in Tree Marathon Racing Shoes: A Randomized Crossover Study. ***Sports Medicine***, 49:133-143, particularly **138-9**.

53. (p. 19) Wear-Test Report. ***Runner's World***, Issue 5, 2021, p. 66.

54. (p. 19) **Thompson**, Jonathan (2021). Fast and Curious. ***The Wall Street Journal***,

August 14-15, p. D5.

55. (p. 21) **Bachman**, Rachel (2021). Nike Spikes Spur Track Turmoil. ***The Wall Street Journal,*** A18, June 15, 2021. Record-Smashing Teen Aims for Olympics. ***The Wall Street Journal,*** A14, June 24, 2021.

56. (p. 23) **Marti**, Barnard et al. (1989). On the epidemiology of running injuries. In *The American Journal of Sports Medicine* 16: 3; 285-294, particularly pages **287** and 291.

57. (p. 25) **Robbins**, Steven E. & Hanna, Adel M. (1987). Running-Related Injury Prevention Through Barefoot Adaptations. In ***Medicine and Science in Sports and Ex****ercise* 19, **148-156**.

58. (p. 26) This would seem to be a classic case of failure in proper risk assessment. As noted by Rickard J. Shinder in an article titled The Age of the 'Unknown Unknowns' appearing in **The Wall Street Journal** on September 18, 2020:

Finding answers to unforeseeable challenges starts with asking the right questions and acknowledging the danger to your enterprise of fully trusting the conventional wisdom. To develop mitigation strategies and create a durable risk-management culture, organizations can start by examining widely accepted shibboleths in unfashionable, heterodox way.

…Risk assessment should be undertaken across an organization, but the ultimate responsibility for driving these efforts rests with the directors. The board should inculcate unconventional thinking throughout the firm.

LIST OF DRAFT FIGURES AND VIDEOS

Note: many figures and videos listed below are currently only temporary markers for final figures still in development. All figures included here are either original work by the author or material in the public domain or an author modification of material in the public domain.

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However, I fully respect the most expansive view of the rights of such copyright owners and therefore will remove any such materials from this online article on the above website if my very limited use is objected to by such owners who formally notify me at the website.

FIGURE 11B (& Video) Still of NBA Final MVP Kawhi Leonard starting to cut during the 2019 NBA Final, taken from video of ABC/TNT television broadcast.

FIGURE 12 (& Video) Still enlargement of Ty Jerome's right shoe of UVA cutting in the NCAA 2019 Semi-final game, taken from video of CBS television broadcast.

FIGURE 13A (& Video) A sequence of video stills of Jamal Murray's left knee ACL tear which occurred when his foot has rolled off the outside edge of his shoe sole.

FIGURE 13B (& Video) A sequence of video stills of Jameson William's left knee ACL tear during the NCAA Division 1 National Championship football game between the Universities of Alabama and Georgia on January 10, 2022 on ESPN.

FIGURES 13C & 13D (& Video) Kawhi Leonard tearing his ACL during a 2021 semi-final NBA Western Conference and Kawhi Leonard in the same position a few weeks earlier in 2021.

FIGURES 13E & 13F (& Video Serena Williams suffering a right knee injury in the 2021 Wimbledon tennis tournament.

FIGURES 13G & 13H (& Video A sequence of video stills of Paige Bueckers suffering a left knee injury in a December 5, 2021, women's basketball game between University of Connecticut and Notre Dame.

FIGURE 13I (& Video) A sequence of video stills of Klay Thompson's left knee ACL tear which occurred when his foot has rolled off the inside edge of his shoe sole.

FIGURE 13J (& Video) A sequence of video stills of Dario Savic's left knee ACL tear which occurred when his foot has rolled into a maximum supination position on his relatively level shoe sole.

FIGURE 14A A published photograph of a statue foot wearing a **caliga sandal** dating from the Roman Empire, from the Bata Shoe Museum, located in Toronto, Ontario, Canada, www.batashoemuseum.ca.

FIGURE 14B A photograph of statue feet from a 2019-2020 Exhibition titled "Worn by the Gods. The Art of shoemaking in the ancient world…" at ***Le Gallerie Degli Uffizi***. www.uffizi.it

FIGURE 15 A 1989 photograph of an outward-tilted bare foot in the **Standing Ankle Sprain Simulation Test** position of maximum supination.

FIGURE 16 A 1989 photograph of an outward-tilted conventional shoe in the same **Standing Ankle Sprain Simulation Test** position of maximum supination.

FIGURE 17 (& Video) A still from a video of six-year-old demonstrating the same **Standing Ankle Sprain Simulation Test** position of maximum supination, with required safety support.

FIGURE 18 A 1989 photograph of an outward-tilted early prototype I constructed with a siped sole, flexible like the bare foot, in the same **Standing Ankle Sprain Simulation Test** position of maximum supination.

FIGURE 19 A schematic diagram of FIGURES 15 & 18 showing the alignment of forces and of FIGURE 16 showing misalignment of forces.

FIGURE 20 A 1997 photograph of a front view of an outward-tilted conventional shoe in the same **Standing Ankle Sprain Simulation Test** position of maximum supination, showing that the tilted ankle joint is outside the outer edge of the shoe sole and therefore not structurally supported by the conventional shoe sole.

FIGURE 21 A 1997 photograph of a front view of an outward-tilted 1993 prototype shoe in a **Standing Ankle Sprain Simulation Test** position of maximum supination, **leaping and landing at about 7 G's,** showing that the tilted ankle joint is aligned with the outer edge of the shoe sole and therefore structurally supported by the prototype shoe sole.

FIGURE 21A A photograph of the 3 plastic layers of the sole of my 1993 prototype: blue outsole, white midsole, and off-white foamed plastic insole.

FIGURE 22 (& Video) A sequence of four video stills of a leaping Test Subject 2 wearing my 1993 prototype landing at 7 G's in the maximum supination position of the Standing Ankle Sprain Simulation Test at the biomechanics laboratory at the University of Massachusetts at Amherst in November, 1993.

FIGURE 23 A lab report from Dr. Ned Frederick of Exeter Research of the force plate landing of Test Subject 2 shown in FIGURE 22 showing the 7 G landing, with for comparison my addition of an informal but safe test result for a conventional shoe in the **Standing Ankle Sprain Simulation Test** with a threshold of pain onset at only .25 G.

FIGURE 24 A video still of Michael Jordan ankle being taped before a basketball game, from ***The Last Dance***, a ten part ESPN 2020 documentary (www.espn.com).

FIGURE 25A A drawing from ***Popular Science*** of the Reebok ***Pump System*** from the 1990's.

FIGURE 25B A video still of a typical in-shoe ankle support system used to prevent ankle sprains (but, at best, only mitigating their damage), taken from video of ABC/TNT television broadcast.

FIGURE 25C A video still of NBA superstar Stephen Curry wearing an in-shoe ankle support system on both right and left foot/ankle complex, taken from video of ABC/TNT television broadcast.

FIGURE 25D A video still of emerging NBA star Trae Young wearing an in-shoe ankle support system on both right and left foot/ankle complex, taken from video of ABC/TNT television broadcast.

FIGURE 25E A video still of NBA superstar Chris Paul strengthening his ankle on a balance beam during a 2021 NBA Conference Final game, taken from video of ABC/TNT television broadcast.

FIGURE 26 A diagram of the **Static Footprint**, showing how the standing foot print is wider than the outline of a conventional shoe sole.

FIGURE 27 An enlargement of a 1980's photograph of Larry Bird's right conventional shoe and lower leg while standing at ease, showing the substantial mismatch between the width of his foot and his athletic shoe, from ***Sports Illustrated***.

FIGURE 28 A diagram of the **Maximum Supination Footprint** superimposed on the outline a conventional shoe sole, showing how the foot automatically rolls off the outside edge of the shoe sole, leaving it with no structural support whatsoever to resist an ankle sprain.

FIGURES 29 & 30 (& Videos) Two video stills of the right conventional shoe and lower leg of Gonzaga's star basketball player, spraining his ankle in the semi-final and the final game of the 2017 NCAA National Championship game, which allowed UNC to win, from CBS television broadcasts.

FIGURES 31-33 (& Videos) Three video stills of NBA superstar Kawhi Leonard's left conventional shoe and lower leg, spraining his ankle in the 2017 NBA playoffs, from ABC/TNT television broadcasts.

FIGURES 31-33 (& Videos) Video stills of two-time NBA MVP Giannis Antetokounmpo, the "Greek Freak", hyperextending his knee during the Eastern Conference final series and his basketball shoe soles.

FIGURE 34 (& Video) A video still of a Division 1 college basketball player rolling both ankles at the same time unassisted during the 2019 NCAA tournament, from a CBS television broadcast.

FIGURE 35 A newspaper photograph of **Michael Jordan** lying in pain after spraining his ankle in a conventional basketball shoe during a NBA game, from ***The Washington Post***.

FIGURE 36 (& Video) A video still of **LeBron James** lying in pain after spraining his left ankle in a conventional shoe during a NBA game, from a ABC/TNT/ESPN television broadcast.

FIGURE 37 (& Video) A video still of **Stephen Curry** spraining his right ankle in a conventional shoe while wearing an in-shoe ankle brace during a NBA game, from a ABC/TNT/ESPN television broadcast.

FIGURES 37A-F (& Video) Video stills of Giannis Antetokounmpo, Anthony Davis, Kyrie Irving, Nicola Jovic, Russell Westbrook, and Trae Young, all spraining their ankles in 2021.

FIGURES 37A-F (& Video) Video stills of Serena Williams rolling her ankle in the 2019 U.S. Open tennis tournament.

FIGURE 38A (& Video) A sequence of three rear view video stills showing how the foot simple rolls off the outside edge of a too narrow conventional shoe sole (for which the upper was removed), showing graphically how an ankle sprain unavoidably occurs due to lack of structural support.

FIGURE 38B (& Video) A sequence of two underneath view video stills of the foot and shoe sole shown in FIGURE 38, showing the thin knife edge of support provided by the conventional shoe sole, in contrast to the wide base of support provided by the bare foot sole.

FIGURES 39A-D (& Video) Video stills showing the artificial misalignment of static forces on the ankle joint of a shod foot and a bare foot for comparison, showing (A) Standing Equilibrium, (B) Initial Stabilizing Ankle Torque, (C) the Tipping Point, and (D) the Final Destabilizing Torque..

FIGURES 39E-F (& Video) Video stills of the external ankle adduction moment (AAM) acting powerfully during lateral motion.

FIGURE 40 A diagram of a **Maximum Pronation Footprint**, superimposed on the outline a conventional shoe sole, showing how the foot automatically rolls off the inside edge of the shoe sole, leaving it with no structural support whatsoever to resist ankle, knee, and other acute and overuse injuries.

FIGURE 41 A video still enlargement of shoe and lower leg showing routine excessive pronation without acute injury in a conventional shoe during a cutting motion occurring in a NBA game, from an ABC/TNT/ESPAN television broadcast.

FIGURE 42 A photographic enlargement of tennis star **Michael Chang's** shoe and lower leg showing extreme pronation without acute injury in a conventional shoe during the French Open, from ***Sports Illustrated***.

FIGURE 43A (& Video) A video still enlargement of poor quality of WNBA superstar **Becky Hammon** tearing her ACL as her foot rolls off the inside edge of the medial forefoot of her conventional shoe sole, from an ABC/TNT/ESPN television broadcast.

FIGURE 43B (& Video) An earlier still of poor quality and obstructed view which seems to indicate that Becky's right foot initially rolled off the outside edge of her shoe sole, like Jamal Murray's left foot in FIGURE 11A &11B.

FIGURE 44 (& Video) A video still of a Division 1 college basketball player injuring his left knee during the 2019 NCAA tournament, from a CBS television broadcast.

FIGURE 45 (& Video) A cropped video still of NBA superstar Stephen Curry injuring his right knee, when his right conventional shoe rolled inward out of control, despite his state-of -the-art in-shoe ankle brace, from an ABC/TNT/ESPN television broadcast.

FIGURE 46 A photograph of a female pronating runner at peak load midstance, showing much more pronation in a conventional running shoe, which is tilted in, so that the lateral heel area is not ground-contacting.

FIGURE 47 A diagram contrasting the full bare footprint of the FIGURE 46 runner at peak load midstance, in contrast to her shod footprint with a major portion of the lateral side non-ground-contacting, particularly in the heel area.

FIGURE 48 Pictures of the ankle bone complex showing the full range of motion of the subtalar joint, from maximum pronation to neutral to maximum supination.

FIGURE 49 A diagram of the wide **Dynamic Footprint**, showing the portions of the footprint that is not physically supported by a conventional shoe sole in maximum supination and maximum pronation.

FIGURE 50 The diagram of FIGURE 50, also showing the bone structures essential to support during maximum pronation and maximum supination.

FIGURE 51 A diagram of the human foot's bones, showing the essential bone structures.

FIGURE 52 A diagram of a dynamic shoe sole with sufficient width to fully support the essential bond structures from maximum pronation to maximum supination.

FIGURE 53 A photograph showing the 1970's superwide **LD-1000** in the outward tilted maximum supination position of the **Standing Ankle Sprain Simulation Test**.

FIGURE 54 Hoka One One website photographs of the superwide TenNine running shoe with heel extension.

FIGURE 55 A late 1980's design exercise I did to illustrate the extra width needed external to a conventional shoe sole to support the wide Dynamic Footprint.

FIGURE 56 A diagram comparing a rigid conventional sole wide enough for the Dynamic Footprint with a similarly wide but flexible prototype design sole that conforms to the shape of a wearer's foot sole, showing how the prototype design sole flats to provide a wide base of support even when tilted outward 30° in supination.

FIGURE 57 A patent drawing from my 6,163,982 U.S. Patent showing the prototype design having a sole with a rounded heel frontal plane cross-section that flattens under a bodyweight load, both when vertical and when tilted outward 30° in supination.

FIGURE 58 A photograph of a frontal plane cross-section of the heel of my 1993 engineering prototype, the midsole in shite and outsole in black, the inner flesh color representing the intended wearer's foot (the insole is not shown).

FIGURE 59 For comparison with FIGURE 58, a photograph of a frontal plane cross-section of the heel of a conventionally unstable shoe which has a thin outsole (off-white) wrapped around a conventionally narrow midsole (black), so the wearer's foot rolls down uncontrollably on either side during extreme supination or pronation.

FIGURE 60 For comparison with FIGURE 58, a photograph of a frontal plane cross-section of the heel of a conventional shoe sole, incorporating a popular gas bladder cushioning system.

FIGURE 60A A classic Adidas **Adilette** slide in frontal plane cross-section taken at mid heel.

FIGURE 60B An Under Armour **Fat Tire** sandal in frontal plane cross-section taken at mid heel.

FIGURE 60C A plastic-foam version of the classic Birkenstock **Arizona** sandal in frontal plane cross-section taken at mid heel.

FIGURE 61 A diagram of a horizontal plane view of my 1993 engineering prototype, showing the enlarged curved sides of the sole abbreviated to bulges relative to a conventional shoe sole, the bulges located around the essential bone structures of the wearer's foot

FIGURE 62 (& Video) A video still of a bare foot landing in a stable maximum supination position when conducting a **Leap & Land Ankle Sprain Simulation Test**.

FIGURE 63 (& Video) A video still underneath view (under thick plexiglass) of both bare feet landing in the same **Leap & Land Ankle Sprain Simulation Test**, showing the wide base of support of the fully supinated bare feet.

FIGURE 64 (& Video) A video still underneath view of test subject attempting to balance on the knife edge of a conventional shoe sole while conducting the **Standing Ankle Sprain Simulation Test.**

FIGURE 65 (& Video) A video still rear view of a running shoe advertised with barefoot-like flexibility, but as unstable as a conventional shoe sole while conducting the **Standing Ankle Sprain Simulation Test.**

FIGURE 66 (& Video) In contrast to FIGURES 64 AND 65, a video still of my 1993 engineering prototype landing in a stable position during the **Leap & Land Ankle Sprain Simulation Test**.

FIGURES 67 & 68 (& Video) In further contrast to FIGURES 64 AND 65, a video still of my 2005 initial stage sole-only prototype landing in a stable position during the **Leap & Land Ankle Sprain Simulation Test**, shown in rear and front views.

FIGURE 69 (& Video) A video still underneath view of a 1997 Adidas Key Trainer athletic shoe, similar to my 1993 engineering prototype landing in a fairly stable position during the **Leap & Land Ankle Sprain Simulation Test.**

FIGURE 70 (& Video) A video still underneath view of my 2005 sole-only prototype slide landing in a stable position during the **Leap & Land Ankle Sprain Simulation Test.**

FIGURE 71 (& Video) A video still underneath view of my 2005 sole-only prototype slide on left foot with bare right foot, both landing in a stable position during the **Leap & Land Ankle Sprain Simulation Test**, with load-bearing footprints shifted forward momentarily to maintain balance.

FIGURE 72 A pressure-sensor footprint while standing in the maximum supination position of the **Ankle Sprain Simulation Test.**

FIGURE 73 (& Video) A video still of an underneath view of a conventional shoe sole landing in an unstable position in the **Leap & Land Ankle Sprain Simulation Test**, with the ankle sprain simulation triggered by stepping on another shoe, in which the test subject is forced to support himself with a safely line.

FIGURE 74 (& Video) A video still of a underneath view of my 2005 sole-only prototype slide landing in a stable position in the **Leap & Land Ankle Sprain Simulation Test**, with the ankle sprain simulation triggered by stepping on another shoe.

FIGURE 75 **(& Video)** A video still of a front view of a conventional shoe sole landing in an <u>un</u>stable position in the **<u>Leap & Land</u> Ankle Sprain Simulation Test**, with the ankle sprain simulation triggered by stepping on another shoe.

FIGURE 76 **(& Video)** A video still of a front view of a bare foot sole landing in a stable position in the **<u>Leap & Land</u> Ankle Sprain Simulation Test**, with the ankle sprain simulation triggered by stepping on another shoe.

FIGURE 77 **(& Video)** A video still of a front view of my 2005 sole-only prototype slide landing in a stable position in the **<u>Leap & Land</u> Ankle Sprain Simulation Test**, with the ankle sprain simulation triggered by stepping on another shoe.

FIGURES 78A & 78B **(& Videos)** Two video stills of a prospective front view the ***IGAR*** prototype slide on left and the Adidas ***Adilette*** slide on the right, the first still with upper straps and the second still with straps removed to show upper contours of the soles.

FIGURES 78C-78F **(& Videos)** Four video stills showing views of the bottom sole surface contours of: the ***IGAR*** slide on left in FIGURE 80; the ***Adilette*** slide on right in FIGURE 81; the ***IGAR*** slide in foreground, the ***Adilette*** in background in FIGURES 82 & 83.

FIGURES 79A-79B Two U.S. Patent drawings that compare the heel and forefoot, respectively, of the ***IGAR*** slide sole 148 (in white) with the ***Adilette*** slide sole, which also includes conventional side extensions 31, which create a flat lower sole surface, instead of the contoured shape of ***IGAR*** sole lower surface, which parallels the shape of the intended wearer's rounded foot sole when unloaded.

FIGURES 80-81 **(& Videos)** Two video stills that contrast the unstable ***Adilette*** slide on the left (rear view) with the relatively stable ***IGAR*** sole on the right (front view) in the **Standing Ankle Sprain Simulation Test**.

FIGURES 82-83 **(& Videos)** Video stills of the ***IGAR*** slide in rear and underneath views performed the **Leap & Land Ankle Sprain Simulation Test** demonstrating good stability.

FIGURE 84 A chart from a ***Footwear News*** article citing <u>comfort</u> as the top purchase influence for both fashion and athletic footwear, from ***NPD Fashionworld Consumer*** July – March 2001.

FIGURES 85A-85B Design patent drawings of the ***ARIG*** slide prototype showing a rounded heel cross-section and rear views.

FIGURES 85C-85B Design patent drawings of the ***ARIG*** slide prototype showing a rounded forefoot cross-section and rear views.

FIGURE 85E Design patent drawing of the ***ARIG*** slide prototype showing a side view.

FIGURE 85F A preproduction drawing showing a cross-section taken about a centerline of the long axis of the **ARIG** slide sole.

FIGURE 85G A design patent drawing of the ***ARIG*** sole showing a side view with a hypothetical shoe upper.

FIGURES 85H-85I Photographs of a slightly modified perspective view and unmodified bottom view of a factory-produced preproduction (size 10) sample of the ***ARIG*** slide sole.

FIGURES 85J, 85K, & 85L Photographs of an overview, a side view, and a perspective view of a factory-produced ***ARIG*** slide sample including a slide upper.

FIGURE 85M A photograph of ***ARIG*** slide sole with slide upper removed and replaced by a fully lasted running shoe upper.

FIGURES 85N & 85Q-85R Photographs of heel, midfoot, and forefoot frontal plane cross sections of the ***ARIG*** slide sole.

FIGURES 85O, 85P & 85Q Classic basketball shoes, the Converse ***All Star*** and the Adidas ***Superstar***, and the classic Crocs ***Clog*** have been modified by simply integrating the ***ARIG Slide*** sole structure into the conventional shoe uppers of the ***All Star***, ***Superstar*** and Crocs ***Clog***.

FIGURE 86 A photograph of the treadmill system capable of postural perturbations with safety harness at

Dr. Kenton Kaufman's gait lab at the **Mayo Clinic** in Rochester, Minnesota, from their website showing their Wounded Warrior prosthetic program.

FIGURES 87A & 87B Copies of the original cover (and my modification correcting of the title) of the book titled ***The Unstable Ankle*** by Meir Nyska and Gideon Mann (Editors) (2002), Human Kinetics, Champaign, Ill.

FIGURE 87C A figure from Asmussen, M., Lichtwark, G., and Maharaj, J. (2021). The "spring-like" function of the subtalar joint in maintaining stability during running. The XXVII Congress of the International Society of Biomechanics (ISB), video presentation on July 28, 2021, Stockholm, Sweden (virtual).

FIGURE 87D X-ray of the reconstruction of an adult woman's ankle that was broken into a complex fracture from a simple slip on gravel.

FIGURES 87E-G Video stills relating to NFL star quarterback Alex Smith's fractured leg injury in 2018, from ESPN's ***Project 11: Alex Smith's Final Drive***.

FIGURES 87H-J Side and underneath of the Nike ***Alpha Menace Pro 2 Mid***, the latest version of the football cleats apparently worn by Alex Smith when he was injured, shown in FIGURE 87H.

FIGURE 87K A video still example of common ankle taping over american football cleats.

FIGURES 87L-P Video stills of Kyle Schwarber's pulled hamstring injury.

FIGURES 87Q-R Video stills of James Harden's pulled hamstring injury.

FIGURE 87T A **CDC** chart of "**The National Estimates of the 10 Leading Causes of Nonfatal Injuries Treated in Hospital Emergency Departments, United States – 2022**."

FIGURE 88A Underneath sole views of many current basketball shoes shown next to a **straight red bar**, 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 are current running shoes.

FIGURE 88B A perspective view of a typical conventional athletic shoe with a **midfoot lateral sole extension.** Also, a modification of FIGURE 49 showing a schematic drawing (overhead view) of a red extension of the shoe sole on the lateral midfoot portion of the lateral side of the sole to provide structural support during excessive supination.

FIGURE 88C Upper and lower schematic views of a conventional athletic shoe with a **midfoot lateral sole extension** with a straight or flat side, as shown **in red** and projecting outward in a bulge shape, as shown in the speckled portion.

FIGURE 88D A photographic underneath view of a well-worn 2021 era Nike running shoe with a **midfoot lateral sole extension** projecting outward in a bulge shape and with a straight yellow line connecting the lateral heel and lateral forefoot.

FIGURE 88D1 A photographic underneath view of a pair of 2022 Nike ***Pegasus*** running shoes, one with a **midfoot lateral sole extension** projecting outward in a bulge shape shown in pink and the other with a **midfoot lateral sole extension** with a straight or flat side shown in white.

FIGURE 88D2 A photographic of the lateral sides of modern basketball shoes that had been modified with the straight-sided **midfoot lateral sole extension,** including the Nike ***Air Jordan XXXVI***, Nike ***Zoom Freak*** 3, Nike ***Zion 1***, Under Armour ***Curry Flow 8***, and Adidas ***D.O.N. Issue #3.***

FIGURES 88E Perspective views of three typical examples of conventional athletic shoes with a **midfoot lateral sole extension.**

FIGURES 88E1 A stock Nike ***Pegasus 38*** as shown in FIGURE 88A modified as shown in FIGURE 88D1 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 the **midfoot lateral sole extension**.

FIGURE 88F Contrasting drawings showing the structural difference between the accepted understanding of the main longitudinal arch of the human foot and a corrected understanding.

FIGURE 88G A photograph of the ***Armor1* ankle roll guard** (for more information, see www.anklerollguard.com).

FIGURES 88H & 88I Side and bottom views of a late 1970's prototype based on an Adidas **Country** running shoe with a lateral midfoot extension of the lateral side of the sole.

FIGURE 88J Prospective rear views of modified and unmodified Adidas marathon shoes showing an early version of a lateral midfoot extension.

FIGURE 89 A modification of FIGURE 88 & 49 showing a schematic drawing (overhead view) of an example supination flexibility axis on a footwear sole.

FIGURE 90 A modification of FIGURE 88 & 49 showing a schematic drawing (overhead view) an example neutral footwear sole with medial and lateral sides that are less wide than those defined by the dynamic footprint that is shown in FIGURE 55.

FIGURE 91A A modification of FIGURE 88 & 49 showing a schematic drawing (overhead view) an example wider shoe sole intended for a supinator wearer, with additional width located on the lateral side.

FIGURE 91B A modification of FIGURE 88 & 49 showing a schematic drawing (overhead view) an example wider shoe sole intended for a pronator wearer, with additional width located on the medial side.

FIGURE 92 Adapted from **Figure 10.183** from ***Sarrafian's Anatomy of the Foot and Ankle***, Third Edition. Armen S. Kelikian, Ed. (2011), Lippincott Williams & Wilkins. Adapted from Hicks, j. H. (1961) The three weight-bearing mechanisms of the foot. In: Evans, F. G. ed. ***Biomechanical Studies of the Musculo-Skeletal System.*** Springfield, IL: Charles C. Thomas.

FIGURE 93 Talus Figure 270 (highlighted) from the ***1918 Edition of Gray's Anatomy.***

FIGURE 94 Talus from Plate XXXI of John Cameron (1934). ***The Skeleton of British Neolithic Man.*** London, Williams & Norgate Ltd.

FIGURES 95-96 Comparative views of the European and Australian Aborigine tibial plateaus (lower surface of the knee joint) from W. Quarry Wood (1920). The Tibia of the Australian Aborigine. In the ***Journal of Anatomy*** Vol. LIV: Parts II & III (January and April): 232-257, Figure 1 on page 235.

FIGURES 97-98 A cropped rear view still photo frame of a Bushman (97) and Shod Finn (98) from a **YouTube** video clip **of *Barefoot running Bushman versus me (shod Finn)*** https://www.youtube.com/watch?v=H1Ej2Qxv0W8. Published on May 26, 2013.

FIGURE 99 Figure 4.5 from page 126 of **Gazzaniga**, Michael S. et al. (2014). ***Cognitive Neuroscience: The Biology of the Mind (4th Ed.)***. New York: W. W. Norton & Company. The torsional-shift anatomical asymmetries between the right and left hemispheres are shown in a bottom view.

FIGURE 100 The Base of the Brain from **Vesalius**, Andreas (1543**)**. ***De Humani Corporis Fabrica Libri Septem***, Basel. From Wikipedia Commons. See also Saunders, JB de CM. and O'Malley, Charles D. (1973). The illustrations from the works of Andreas Vesalius of Brussels. New York: Dover.

FIGURE 101 A warning symbol is superimposed on the conventional shoe photograph of FIGURE 14.

APPENDIX FIGURES

FIGURE A A photograph of the version of **my 1993 prototype** that was prepared for and loaned temporarily to Nike R&D staff in 1994 during initial licensing discussions.

FIGURE AB The uppermost portion of an article titled "Technology 96: Bare vs. Air" in ***SPORTSTYLE*** magazine, January, 1996, p. 40.

FIGURE B A video still from the Nike website (circa 2005) on the Free line of running shoes, showing a barefoot landing on grass during running.

FIGURE C An enlarged photograph of the foot of a running man (Plate 23, Frame 3), from Eadweard Muybridge's pioneering motion photography of published in 1887 and republished in an edition titled ***The Human Figure in Motion***, 1955, Dover Publications, Inc., New York, N.Y.

FIGURE D A photograph of the forefoot of the original model of a Nike ***Free*** running shoe, showing the ineffective sipes located over the big toe.

FIGURES E Photographs of typical examples of Nike and Adidas running shoes with a reinforced area in the shoe upper over the big toe area of the forefoot.

FIGURE F A photograph of the popular 1998 Adidas ***Crazy 8*** basketball shoe model of the ***Feet You Wear*** line.

FIGURE G A photograph of the 2018 Adidas basketball shoe model ***Crazy BYW (Boost You Wear).***

FIGURE H A photograph of the 2019 Adidas basketball shoe model ***Crazy BYW 2.0 (Boost You Wear).***

FIGURE I A photograph of the 2020 Adidas basketball shoe model ***Crazy BYW III (Boost You Wear).***

FIGURE J A photograph of the 2018 Nike distance racing shoe model ***Vaporfly.***

FIGURE K A photograph of the 2019 Nike distance racing shoe model ***Vaporfly NEXT%.***

FIGURE L A photograph of the Nike ***Air Zoom Victory*** **"**super spike" track racing shoe.

FIGURE M A photograph of an ***Amsterdam*** shoe last for women from Podohub.com.

FIGURE N A photograph of an ***Athens*** zero drop shoe last for women from Podohub.com.

FIGURE O A photograph of a ***Dallas*** shoe last for men from Podohub.com.

FIGURE P A photograph of the 2020 Nike running shoe model ***React Infinity Run.***

FIGURE Q A photograph of a 2000's Nike running shoe model with ***Shox*** cushioning technology.

FIGURE R A photograph of the 2020 Nike running shoe model ***Joyride Dual Run.***

FIGURE S A photograph of the 2018 Nike running shoe model ***Free RN 5.0.***

FIGURE T A photograph of the 2018 Nike running shoe model ***Zoom Pegasus Turbo 2.***

FIGURE U A selected part of page 40 from January, 1996, issue of ***SPORTSTYLE***.

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