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Running the Wrong Way?

Modern running shoes feature heels packed with cushioning technology—but do they prevent the foot from functioning as it was designed?

By Dr. Lon Kilgore **March 2010**

Susannah Dy/CrossFit Journal

Humans are built to move. They walk. They jog. They run.

The basic structure of the human foot has not changed significantly for some four to five million years. It is an interesting design with many supportive and shock-absorbing elements that make bipedal movement both possible and safe. We have supporting arches that carry the weight of the entire body and virtually any load placed upon it. The many joints comprising the arches are quite well endowed with a multitude of muscles, tendons and ligaments. When the foot contacts the earth underneath it during movement, the joints in the arches flex in order to dampen the forces encountered.

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The foot is purposeful and wonderfully engineered, perfectly constructed to carry out its function. Da Vinci's Renaissance depiction of foot anatomy, drawn from specimens, led him to state, "The human foot is a masterpiece of engineering and a work of art." Due to its ability to support, the arch plays a central role in many of Da Vinci's architectural works.

When we consider the range of human activity and any possibility of anatomical predisposition to injury, one would assume that during the many millennia of human history, regular advances in technology would either reduce injury rates or improve locomotive function if there was indeed an environmental challenge and need. Strangely, such advances were not seen until the past century or so, a pitifully small segment of human history. Why? We consider shoe design to be a major component of exercise performance today, so why did our ancestors avoid improving shoe design and function? And how do we know they didn't?

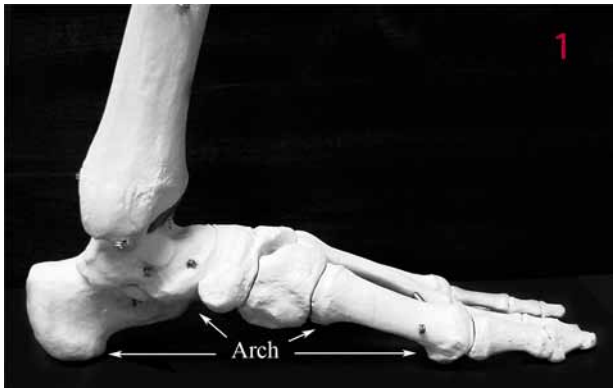

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Figure 1: The longitudinal arch of the foot forms an effective supportive and shock-absorbing structure. The transverse arch (running across the ball of the foot) also performs similar functions. An analogous structure would be leaf springs in a car's suspension—quite robust.

To ferret out more about this little niche of history, all we need to do is visit any well-inventoried art museum. Look at the depictions of humans at work, play or war. In every era and locale of art history, you will see the human foot represented during walking, running, lifting and standing. The only modifications you will usually see to the bare foot are thin sandals to protect the foot from sharp objects, and you will see cloth or leather wraps to protect the foot from cold.

Semblances of what we know as the shoe appeared no less than 5,300 years ago. Preventing cuts or frostbite represented an amazing advance, but today we would perceive those early shoes as very low-tech solutions to simple problems. From their first appearance, sandals and wrappings for the foot only varied in materials and construction, not in elementary structure or purpose.

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Figure 2: Pre-Christian Egyptian artifacts illustrate bare feet (as depicted here) or sandals as typical footwear. *(Photographed at the Dallas Museum of Art)*

Figure 3: Greek art of the third century B.C. depicts bare feet, low sandals (3L) or high sandals (3R). *(Photographed at the Dallas Museum of Art)*

Figure 4: Mexican artifacts from approximately 100 B.C. predominantly show bare feet.
(Photographed at the Dallas Museum of Art)

Figure 5: A Roman sarcophagus from the second century shows a mounted soldier with even-thickness sandals in battle. *(Photographed at the Dallas Museum of Art)*

Let's be critical here. If, as Da Vinci postulated, the foot is amazingly well suited to supporting and transferring force, why would we and why do we have super-duper-air-gel-matrix-torsion-cushiony shoes that are touted to be the pinnacle of performance footwear? Why try to improve upon something already well suited to its function? Why recreate the wheel, so to speak?

If, as Da Vinci postulated, the foot is amazingly well suited to supporting and transferring force … why do we have super-duper-air-gel-matrix-torsion-cushiony shoes?

The evolution of athletic footwear is quite troubling in terms of solving or, at worst, producing technical problems with exercise. Our ancestors functioned quite well in minimalist footwear or with none at all. How has the human condition changed so much for us to "need" advanced insoles, cushions and even one particular structural shoe element we take for granted: the elevated heel?

Let's tackle this issue in two parts: the evolution of the heel and the evolution of shoe cushioning. Ideally, we should find that the addition of the heel and cushioning solved some identified problem in movement.

Heel History

As we have noted already, the heeled shoe does not appear in art of antiquity. Unsubstantiated or even substantiated stories about where the heel came from are sparse. Three plausible explanations exist.

The first would be that the Romans added height to the rear sole of their soldier's footwear to increase stride length, thus enabling them to cover more distance with the same number of strides. That sounds like something a military organization might actually do, but records or artistic depictions of this are not present in available archives (see Figure 5). And why would they elevate only the heel? A thicker sole along the entire length of the shoe would have accomplished the same purpose and would have been easier to produce.

A second possible origination for shoe heels is attributed to the Hungarian Hussars (mounted military troops) somewhere during the 15th century (compare figures 5 and 6). It is surmised that the heeled boots they sported were designed specifically to add stability and control to the foot-stirrup interface. An astute student with a cowboy background once surmised that the heeled boot would also enable the rider to "kick the crap out of foot soldiers." The art of the era is replete with depictions of Hussars in heeled boots.

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Figure 6: The boots worn by the Hussars influenced cavalries throughout Europe, and heeled footwear remained common following their introduction. Equestrian events such as horse racing used, and continue to use, low-heeled boots.
(Photographed at the Dallas Museum of Art)

The last commonly espoused origin of the heel traces back to Catherine de Medici in the mid-1500s. It has been suggested she was sensitive of her diminutive stature and used the elevated heels to boost her physical presence. Some evidence suggests heeled shoes existed in Italy in the years prior to de Medici, but she is believed to be the popularizing factor in their wear by nobles and the aristocracy. This is a trend in footwear (and fashion in general) we will see repeated throughout history: members of the general population are swayed more by elite endorsement than actual function.

So we have three basic possible reasons for the development of the heel: increased stride length, stirrup control and vanity. In terms of running or human movement, the highly tenuous suggestion that the Romans used the elevated heel to increase the stride length of their soldiers is the only performance-enhancing explanation for the heel. Getting marching troops from point A to point B faster than your enemy is important, but if heels really provided a significant tactical advantage, wouldn't we have seen other military forces adopting the use of the heel in their footwear? We don't see evidence of this in pictorial references from other contemporary or subsequent civilizations influenced by the Romans.

The other two historical possibilities, although documentable, do not provide for a benefit to human walking or running performance.

So how did we end up with heels on running shoes? And do they actually do anything to improve performance—or do they do something dastardly?

So how did we end up with heels on running shoes? And do they actually do anything to improve performance—or do they do something dastardly, like introduce an artificial running environment facilitating the introduction of a non-native running technique?

Do an experiment. Take your shoes off and run down a street or other hard surface. Run fast and run slow. How do you run? If you are normal, you will probably contact the ground with the ball of your foot first with every stride. You do this intuitively without thinking because your body is doing what it is designed to do. In this case, the arches of the feet are absorbing the impact forces, allowing you to run safely, comfortably and without injury. If you are on pavement, you will have a hard time convincing your body to allow you to run with a heel strike. With bare feet, it is very jarring. (You can do the same exercise by running in place: your body will not let you do a heel strike unless you force it).

So it is natural to have a ball-of-foot strike and not so natural to have a heel strike when running in bare feet. If we were destined to be more robust and efficient with a heel strike, would we not have evolved to run in that manner intuitively and under all conditions, especially those to which we have been exposed throughout human history?

Let's think back to the Romans. If an elevated heel (or sole) allowed a marching army to cover more distance, would this idea extend to running shoes? Would a shoe with a heel allow a runner to cover the same distance with fewer strides than a thin, flat sole (or no shoe)?

The Experiment

It's time for another experiment. Put on your best and most fluffy running shoes. Take one step forward to a heel-down and toe-up position (leave your trailing leg behind). Note the distance of the foot-contact point from your body. Now, slowly point your toe down until the ball of the foot is in contact with the ground and your heel is slightly elevated. How far is the point of contact away from your body now? An interesting observation, no?

It looks as though a ball-of-foot strike adds more distance to stride length than a strike with an elevated heel. So assuming our turnover rate is the same between conditions, it appears we will run faster with a ball-of-foot strike than a heel strike with an elevated heel. In actuality, the presence of a heel is a non-contributor in attaining maximal running velocity. If you want to verify this, just look at the footwear of sprinting athletes and do a video analysis of their foot strikes: fast runners do not used heeled running shoes and do not heel-strike.

But there is more to it than this, and we can't just dismiss the heel's possible benefits before examining a couple of issues. The first is that an army is usually marching, not running, so a thicker heel just might achieve a step-reducing objective effectively over long distances. The added thickness would also likely have extended the life of the shoe as well. Durable military equipment is a necessity, and there may be a similar benefit with running shoes in the present.

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Finally, most consumers of elevated-heel running shoes are not racers or even recreational runners. They are the average persons of modernity, those who spend the majority of their ambulatory lives walking, and they will do so in the heel-toe gait we develop naturally in childhood. The possibility that an elevated heel will get us from point A to B a minuscule number of seconds faster during our workday is of little concern. We are by and large a sedentary society and do not cover significant distances other than by car. The heel really provides no viable performance advantage, so why have them? We need to consider an alternative viewpoint.

Cushioning History

Could the value of the modern running shoe lie in the cushioning?

Shoe cushioning and cushioned supports are an invention of modernity. The evolution of what we know as the running shoe, cross-trainer, tennis shoe, sneaker, trainer, etc. was made possible by Charles Goodyear's rubber-vulcanization process. Patented in 1844 and widely used within a decade, the process made rubber heat- and cold-resistant (boat shoes constructed from native rubber in the 1820s failed to tolerate environmental demands). Goodyear's process allowed rubber's unique characteristics to be exploited year round in a variety of applications.

By the late 1800s, shoes were being manufactured from canvas (or kangaroo skin) and vulcanized rubber. These early shoes were not intended for performance enhancement or athletics at all; rather they were an attempt to produce an inexpensive shoe to market to the public. Both US Rubber (Goodyear) and Colchester Rubber Companies produced these shoes before 1900.

These early rubber shoes, gum-shoes, sneakers or plimsolls were rapidly noticed by athletes and coaches in sports played on hard surfaces. Their ability to reduce slipping was more useful to performance than their hard-soled predecessors. The Spalding Company introduced a basketball shoe in 1907. By 1917, US Rubber was marketing a rubber "tennis shoe," and the Converse Shoe Company had introduced its basketball shoe, the All-Star (re-named Chuck Taylor All-Stars in 1923). All these early sports shoes shared similar construction with essentially flat soles and insoles and canvas uppers, and the guts of athletic shoes for the general public remained static for about 25 years save for the incorporation of new synthetic materials and superficial design elements for marketing purposes.

Although the appearance of supports and cushioning in shoes occurred at essentially the same time as rubber shoes developed, they are independent events and do not share a common history until very recent decades. The first supportive or cushioning element for shoes is widely attributed to William Riley who, in 1906, developed an arch support for wait staff and other workers who spent long hours on their feet. This arch-support company would later evolve into the New Balance shoe company in the second half of the century. The use of rubber as a cushioning element in work shoes was actually elaborated in Butterfield's 1900 patent application for shock-absorbing work boots. And the most famous proponent of cushioning and support, Dr. Scholl, patented his first arch support in 1911.

Could the value of the modern running shoe lie in the cushioning?

The first intersection of the worlds of cushioned-support and sports shoes occurred in the 1930s, when US Rubber released a shock-proof arch cushion in their Keds line of shoes. Germany's Adidas also included arch support in their athletic shoes. It is prudent to note here that Keds were all-purpose shoes and not intended solely for sports.

Even with the arch support in place, the heel of these shoes, and all running shoes, remained at virtually the same level as the forefoot, a design that had not changed for millennia.

In 1962 New Balance introduced the Trackster running shoe. It had a unique rippled sole, a mild wedge heel and arch support. In the same year, Phil Knight and Bill Bowerman partnered to form Blue Ribbon Sports Inc., the predecessor to Nike Inc. In 1972, Nike released the Waffle Racer with waffled soles, a mild wedged heel and a cushioned midsole.

Since that time, the race has been on—so to speak—in the development of cushioning for running shoes. Terasaki patented an air-cushioning device in 1972, and since then hundreds and hundreds of cushioning

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and force-dampening gimmicks have been included in running shoes, all marketed to the exercising public under the premises of safety, comfort and performance.

Footwear and Running Technique

Now we get to a controversial part: even though athletic shoe companies have an ever-growing menu of shoes with an ever-growing number of features, the shoes that win races, sprints and up, have not changed much in concept or construction since the early 20th century. Look at Nike's newest Zoom Miler and compare it to the Adidas shoe worn by legendary Czech distance runner Emil Zapotek in 1948. You will see similar structure; minimal heel, some support and cushioning, lightweight upper, laces—and that's about it (Figure 7).

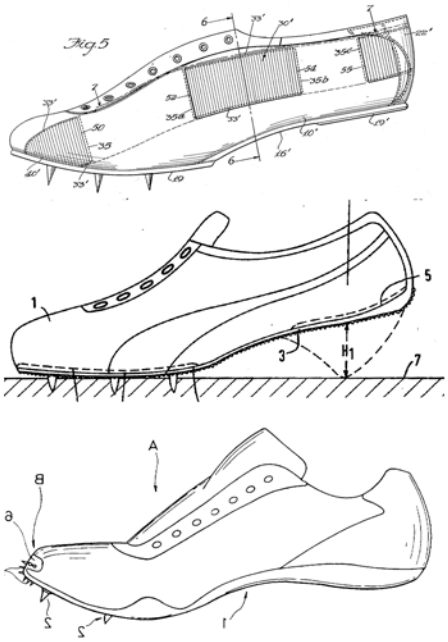

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Figure 7: Comparison of a track shoe from 1951 (top, from patent by Shapiro), a Puma track shoe from the '70s (middle, from 1978 patent by Dassler) and a Mizuno track shoe from 1998 (bottom, from patent by Kaneko).

So why no super cushioning and big fluffy heels in competitive running shoes? Easy: performance. Can you jump higher barefooted or with big marshmallows on the bottom of your feet? Bare-footed, of course. The less compressible material between your feet and the earth, the better we will be able to transfer force to move our bodies.

A track flat does not absorb or dissipate the force you are generating with the muscles that move you. A track flat gets you out of the blocks faster, helps accelerate you faster, and helps you maintain running velocity. Now this is assuming you run with good technique—and this is a big assumption.

How many people have actually been taught how to run? If your learning experience in running for athletics is similar to mine, it involves a football coach telling you to go run around the field. No one ever actually took the time (or, more likely, knew how) to teach efficient and safe running technique. No one ever bothered to correct heel-strike running technique in favor of faster, more efficient, shock-absorbing strikes with the ball of the foot. A plethora of other flaws were similarly ignored.

Right now, you are probably questioning all of this because shoe design is purported to be highly scientific. All highly engineered modern sports shoes are supposed to be safer and perform better aren't they? Well, it's sort of a quagmire. If you run with a heel-strike technique—a technique that maximizes repetitive shock to the body—yes, those cushy heels and marshmallow insoles will dampen the forces experienced and maybe fend off a case of shin splints or a stress fracture or two.

In fact, in Blue Ribbon Sport's (a.k.a., Nike's) 1976 patent application, reduction of injury for runners who heel-strike during running was the design goal, not improvement of performance (most performance-improvement claims for running shoes have been focused on the development of track-spike technology). Cushioning for heel strikers is the "pro" of high-tech cushioned running shoes.

No one ever bothered to correct heel-strike running technique in favor of faster, more efficient, shock-absorbing strikes with the ball of the foot.

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The "con" is they can actually facilitate running with poor technique by virtue of allowing the runner to bypass his innate shock-absorptive elements, the arches of his feet, to land on the heel. When you use a heel-strike technique, the calcaneous (heel bone), is abruptly loaded with force that would have been dissipated if the force had passed through the arches.

Defeating the body's protective anatomy is risky. This also causes a transient deceleration of the body (so much for running fast). Furthermore, wearing big, cushy shoes increases the chance of rolling an ankle. Marshmallow feet change proprioception, balance and foot stability. You can see this in any individual wearing heavily cushioned shoes. They minutely sway back and forth as their postural reflexes constantly search to find a center of balance. Add movement into the mix and the body is hard-pressed to find the constant and repetitive center of balance that's needed for consistent technique of any kind.

Here is more heresy: Learning correct running technique is more important than your shoes.

So by wearing cushioned shoes, are we trading one injury for another? Should we wear cushioned shoes with elevated heels or should we wear flatter shoes? This is a hard question to answer. But given the misguided conventional wisdom that long, slow, distance is the best way to get "fit," coupled with the normal human tendency toward a "more is better" mentality, people will run way too many very slow miles way too often to actually improve fitness. In such a case, especially if no *experienced and competent* running coach is available, then spending the money on cushioning tech is probably wise.

Here is more heresy: Learning correct running technique is more important than your shoes. How would I describe appropriate running technique? Remember, arches are built to support our weight during all ambulation. Spend some money on learning how to run on the balls of your feet. If you are a fitness professional, learn how to teach running. Learn how to correct bad technique through a running/endurance certification. Learn how to teach a variety of running events by attending a USA Track & Field coaching course.

Online running gurus will disagree with all this and spout conventional wisdom: "Look at all those endurance runners who heel-strike: they run fast, and that means they can't be wrong." They will also probably say, "Running on the toes or balls of the feet is fine for sprinters, but you can't keep it up for a long distance or a long time." They will, of course, point to the Boston Marathon racers wearing well-padded shoes as a point of support.

OK. Let's consider long-distance runners. Like any athlete who competes in varied environments, these runners will have multiple shoes for racing in specific conditions and for training (Figure 8). A competitive marathon is a very specific environment that produces profound fatigue, and with fatigue, exercise technique decays. I maintain that a "racer" will be able to use correct running technique throughout a marathon with correct training and minimal heel cushioning. However, a "runner" will likely not be so well prepared, and the big, cushy shoes will likely be a godsend of comfort.

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Figure 8: Three shoes for three different purposes. These shoes, used by an NCAA distance runner, are for shorter cross-country racing (top), longer hard-surface racing (middle), and training (bottom). This particular runner contacts the ground first with the ball of the foot during racing and interchangeably with the ball of the foot or heel during training, depending on the tempo of the training run. There seems to be a relationship between duration of run and cushioning. Shorter cross-country races have the least cushioning and lowest heel. Longer road races use a minimal heel cushion. And since runners love to put in the miles, the trainers experience the highest single-session mileage and are the most extensively padded. They also have the largest sole area for distribution of impact. Do runners heel-strike from fatigue or do they use inefficient technique because the shoes allow it?

For clarity, we are using the Hunter S. Thompson definition of racers and runners from his description of Honolulu Marathon participants in *The Curse of Lono* (1983):

"The racers run smoothly, with a fine-tuned stride like a Wankel rotary engine. No wasted energy, no fighting the street or bouncing along like a jogger. These people flow, and they flow very fast. The runners are different. Very few of them flow, and not many run fast. And the slower they are, the more noise they make. By the time the four-digit numbers came by, the sound of the race was disturbingly loud and disorganized. The smooth rolling hiss of the racers had degenerated into a hell broth of slapping and pounding feet."

Racers are in contention to win. Runners are in contention to finish.

But in reality, how many of the millions of recreational runners actually run marathons? Not a large percentage. So the vast majority of recreational runners will run just a few miles in a session and can adapt their musculature to accommodate correct forefoot-strike technique throughout the exercise session, and they will be better served with little heel and little cushion.

Fluffy shoes provide a crutch, an easy out, an ability to develop poor technique—especially in those who have not been coached.

Still skeptical? Let's do another experiment. Get up, take your shoes off and start running in place. Which gives out first, your cardiorespiratory endurance or your calves? You'll probably get bored before finding an answer, but I hope you get the point. Even if your calf muscles start to ache, guess what? They can be trained to last longer, and they will adapt just like any other muscle used in endurance running. Fluffy shoes provide a crutch, an easy out, an ability to develop poor technique—especially in those who have not been coached. You *can* run safely in running flats, but like any other exercise activity, there is

a need for common sense and progression. Wholesale changes in technique and equipment require time and titration to facilitate learning and safety.

And now for the obvious: a cushy pair of high-tech running shoes won't make you run faster. Intuitively you know this. How many times have you seen a child with new shoes running around like crazy and asking, "Am I faster?" What do you tell them?

High-tech and force-dampening shoes do not make you go faster; good technique and appropriate conditioning of the human body do. Add a pair of flats, and off you go to the races.

Editor's note: *After this article was written, the journal* ***Nature*** *released the results of a Harvard study in which Daniel E. Lieberman suggested that running shoes indeed changed the mechanics of locomotion to encourage a heel strike that can create more impact.*

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About the Author

Lon Kilgore is a professor at Midwestern State University, where he teaches applied physiology and anatomy. He has also held faculty appointments at Kansas State University and Warnborough University (IE). He graduated from Lincoln University with a Bachelor of Science in biology and earned a PhD in anatomy and physiology from Kansas State University. He has competed in weightlifting to the national level since 1972 and coached his first athletes to national championship event medals in 1974.

He has worked in the trenches, as a coach or scientific consultant, with athletes from rank novices to professionals and the Olympic elite, and as a collegiate strength coach. He has been a certifying instructor for U.S.A. Weightlifting for more than a decade and a frequent lecturer at events at the U.S. Olympic Training Center. His illustration and authorship efforts include books, magazine columns and research journal publications.

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