The Barefoot Debate: Can Minimalist Shoes Reduce Running-Related Injuries?

Jeffrey A. Rixe, BA[1]; Robert A. Gallo, MD[2]; and Matthew L. Silvis, MD[2,3]

Abstract

Running has evolved throughout history from a necessary form of locomotion to an athletic and recreational pursuit. During this transition, our barefoot ancestors developed footwear. By the late 1970s, running popularity surged, and footwear manufacturers developed the running shoe. Despite new shoe technology and expert advice, runners still face high injury rates, which have yet to decline. Recently, ''minimalist'' running, marked by a soft forefoot strike and shorter, quicker strides, has become increasingly popular within the running community. Biomechanical studies have suggested that these features of barefoot-style running may lead to a reduction in injury rates. After conducting more outcomes-based research, minimalist footwear and gait retraining may serve as new methods to reduce injuries within the running population.

Introduction

Running has evolved from a necessary form of locomotion to a recreational pursuit. During this transition, our barefoot ancestors developed footwear, which, through modifications over the ensuing millennia, has transformed into the modern running shoe. Despite these running shoe modifications, runners continue to experience high injury rates with no evidence of decline. Recently, "minimalist" running, which is characterized by soft forefoot strike and shorter, quicker strides, has reemerged within the running community as a method to limit running-related overuse injuries. The purpose of this article was to review the history of running and development of the modern running shoe, outline the current pitfalls with the modern running shoe, and discuss the potential benefits and risks of "minimalist" running.

[1]College of Medicine, Pennsylvania State University Hershey, Hershey, PA; [2]Department of Orthopedics and Rehabilitation, College of Medicine, Pennsylvania State University Hershey, Hershey, PA; and [3]Department of Family and Community Medicine, College of Medicine, Pennsylvania State University Hershey, Hershey, PA

Address for correspondence: Matthew L. Silvis, MD, Departments of Family and Community Medicine and Orthopedics and Rehabilitation, Pennsylvania State University Hershey, Mail Code H154, 500 University Drive, Hershey, PA 17033; E-mail: msilvis@hmc.psu.edu

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History of Long-Distance Running and Development of the Modern Running Shoe

Humans have been running barefoot or with "minimalist" footwear for millennia. Anthropologists suggest that walking began at least 4.4 million years ago with our hominid ancestors, the australopithecines, and endurance running followed over 2 million years later with the "barefooted" *Homo erectus* species (3). The beginning of the end for the "barefoot era" occurred over 30,000 years ago when protective footwear became habitual as a means to protect against acute injury, such as stepping on a sharp rock or scorching hot sand (9). The earliest preserved samples of these shoes, resembling sandals or thin leather slip-ons, date back at least 8,300 years (23). Eventually, footwear evolved beyond a protective role and gained cultural respect as a status symbol (37). A wide variety of shoe modifications were introduced to alter the natural function and/or appearance of the human foot: Mesopotamian rulers in 883 BC added wedges to their sandals for increased height, while Greek actors wore thick-soled shoes for the same purpose.

Despite these early modifications in shoe design, the running shoe remained neglected by shoe manufacturers until only four decades ago. A series of events, including (a) Dr. Kenneth Cooper's 1968 book, *Aerobics* (6), which advocated running as a form of exercise to quickly reach high levels of fitness; (b) American Frank Shorter's marathon victory at the 1972 Olympic Games in Munich; and (c) Jim Fixx's 1977 best-selling *The Complete Book of Running* (16), a comprehensive start-up guide for amateur runners, sparked a "running boom" in the 1970s. This "running boom" blossomed into a legion of endurance runners that includes between 3 and 6 million Americans annually (15).

The rise in participants fueled the advent of the multibillion dollar running shoe industry. While initial running shoe designs were little more than standard tennis shoes,

footwear companies, such as Nike, began fashioning running shoes that featured cushioned, waffled soles to increase comfort and decrease the physical stresses of repetitive impact. The success of these models made the cushioned sole a standard within the industry despite any scientific evidence to confirm its efficacy in reducing injury in the sport.

Advances in running shoe technology continue to focus upon injury reduction. The latest fad in running shoe evolution has been the development of specific running shoes and orthotic inserts to accommodate the variable arches and foot shapes among runners. Three common recommendations include (a) motion control shoes for low arches, (b) cushioned trainer shoes for high arches, and (c) stability shoes for normal arches (1,5). While these modifications have gained popularity within the running community as a means to combat injury, there is currently limited data to suggest that these measures based on arch type or foot shape can reduce injury rates (13,20,22,30).

Current State of Running Injuries

Despite the "advances" in running shoe technology and scores of expert training guides, endurance running injury rates have remained relatively constant throughout the past 30 years: 50% of runners, then and now, incur an injury annually with 25% of runners injured at any moment (15). The vast majority of these injuries involve the knee, leg, and foot (38). Risk factors for development of running-related injury have been characterized broadly into four categories, which include systemic (age, gender, weight, knee alignment, arch type, flexibility), running-/training-related (training frequency/alterations/terrain, race distance, running experience, shoe age, pace), health (previous injury, medical problems), and lifestyle factors (alcohol use, smoking, cross-training) (38). While risk factors from each category have been correlated with increased and/or decreased injury rates, researchers and runners tend to focus upon modifying systemic and running-/training-related factors to limit the overall force subjected to the lower extremities during running and thereby preventing injury.

Much of the data regarding training regimens remain inconclusive (4,21). Nonetheless, research has demonstrated that (a) increasing mileage increases the risk of injury (18,26,39) and (b) certain anatomic variables are correlated with specific injuries. Notably, greater foot pronation correlates with shin splints (18,28), greater quadriceps angle correlates with patellofemoral pain (7,25), higher arches correlate with bony related injuries (41), and lower arches correlate with soft tissue damage (41). Prospective injury studies have found similar associations, linking both higher and lower than normal arches to all injuries, excessive or reduced hind-foot inversion to more stress fractures, greater knee valgus with all injuries, and higher tubercle sulcus angles with shin splints (39). Unfortunately, many endurance runners are unable and/or unwilling to decrease mileage, and the aforementioned previous efforts focusing upon correcting anatomic variables via orthotics and/or shoe modifications have not produced significant reductions in injury rates (20,22,30).

A growing faction of runners has turned their attention to dynamic running factors, *i.e.*, "running form," as a potential method of reducing injury rates. In its simplest form, normal running gait begins with a lateral heel strike, followed by foot pronation during mid stance and foot supination during push-off (12,14). When runners land in heel strike, ground reaction forces reach 1.5 to 3 times body weight (24). Proper running gait is critical to absorb the impact of striking the ground and dissipate force throughout the kinetic chain of muscles, ligaments, tendons, and bones (14). In a study of exercise-related lower leg pain among undergraduate physical education students, subjects with pain had altered running patterns before the onset of injury (40). Specifically, injured individuals had markedly increased heel strike, pronation, medial-sided foot pressure, and lateral roll-off compared with their peers (40).

Recent research has demonstrated the effectiveness of gait training in reducing tibial stress fractures (8). In a recent study, 10 recreational heel-striking runners participated in gait retraining sessions. In each session, participants ran on a treadmill while watching the signal from a tibial accelerometer on a computer screen. Researchers gave simple instructions to help participants adjust to reduce the measured impact forces in real time. After 4 wk of training, participants had significant reductions in peak positive tibial acceleration, vertical instantaneous loading rate, vertical impact peak, and vertical average loading rate. Any increase in these measures in previous studies has been shown to increase stress fracture risk. The reductions observed from gait training more than double the observed effect with orthotic inserts. Gait retraining thus seems to be a potentially viable option for preventing tibial stress fractures and possibly other running-related injuries (29).

The Rise of Minimalism

Amid this environment and spurred by Christopher McDougall's 2009 publication *Born to Run: A Hidden Tribe, Superathletes, and the Greatest Race the World Has Never Seen* (27), the "minimalist" movement has infiltrated the endurance running community. In his groundbreaking best seller, McDougall (27) described the unique running style of the Tarahumara Indians: members of this tribe from Mexico's Copper Canyon routinely run hundreds of miles per week wearing sandals with tire-tread soles. Instead of running with long strides and a pronounced heel strike, these runners used a "barefoot style" characterized by a short stride, light steps, and footwear with minimal protection and maximal flexibility (27).

Within the past few years, a growing body of biomechanics research, summarized in Table 1, has emerged to support the biomechanical advantages of "barefoot" running. By landing with a forefoot and/or midfoot strike rather than with a heel strike, "minimalist" runners are able to disperse impact forces more efficiently (27). Furthermore, even on hard surfaces, "barefoot" runners generate smaller collision forces than individuals wearing standard cushioned running shoes (24). The ability of "minimalist" runners to absorb impact more efficiently than shod runners has been hypothesized to result from adaptations of dense collection of plantar mechanoreceptors that "feel the ground"; the somatosensory feedback is likely diminished in shod runners (31,32,36). Arch supports and orthotics may interfere

Table 1.
Biomechanics research summary: barefoot versus shod running.

Biomechanics Measurement	Barefoot	Shod	Sources
Abnormal joint torques at the hip, knee, and ankle	Decreased	Increased	Kerrigan *et al.* (19)
Ankle motion in stride	Increased	Decreased	Bishop *et al.* (2), Lieberman *et al.* (24)
Braking and pushing impulses	Higher	Lower	Divert *et al.* (10)
Distribution of plantar pressures	Evenly over time and foot surface	Concentrated at the heel immediately at time of impact	D'Aout *et al.* (9)
Foot position at landing	Plantarflexion, mid foot, forefoot (m)	Dorsiflexion, heel strike, rear-foot strike	Bishop *et al.* (2), Lieberman *et al.* (24), Squadrone and Gallozi (35)
Foot width	Increased	Decreased	D'Aout *et al.* (9)
Ground contact time and flight time	Decreased	Increased	Divert *et al.* (10), Squadrone and Gallozi (35)
Leg stiffness	Decreased	Increased	Bishop *et al.* (2)
Net running efficiency	Increased	Decreased	Divert *et al.* (11), Squadrone and Gallozi (35)
Peak tibia internal rotation	Not assessed	Decreased — in low-arch runners wearing motion control shoes	Butler *et al.* (5)
Perceived risk of injury	Lower	Normal to higher, regardless of shoe	Divert *et al.* (10), Kerrigan *et al.* (19), Knapik *et al.* (20), Knapik *et al.* (22), Liberman *et al.* (24), Robbins and Hanna (31), Robbins *et al.* (32), Robbins *et al.* (33), Squadrone and Gallozi (35)
Preactivation of the triceps surae	Increased	Decreased	Divert *et al.* (10)
"Protective" somatosensory feedback	Increased	Decreased	Robbins and Hanna (31), Robbins *et al.* (32), Robbins *et al.* (33)
Stride frequency	Increased	Decreased	Divert *et al.* (11), Squadrone and Gallozi (35)
Stride length	Decreased	Increased	Kerrigan *et al.* (19), Squadrone and Gallozi (35)
Tibia shock/acceleration	Decreased — with biofeedback gait retraining	Decreased — in high-arch runners wearing cushioned trainers	Butler *et al.* (5), Crowell and Davis (8)
Toe movement: hyperextension before contact	Normal	Restricted	Stewart (37)
Vertical impact peak/collision force	Decreased (m)	Increased	Crowell and Davis (8), D'Aout *et al.* (9), Divert *et al.* (10), Robbins and Hanna (31), Squadrone and Gallozi (35)

m, applies to minimalist shoes.

further with the downward deflection of the medial arch upon loading and blunt the innate protective mechanism (32).

To date, no clinical studies have been published to substantiate the claims of injury reduction using a "minimalist" style. Opponents of "barefoot" running maintain that the "minimalist" style may alter the type, not incidence, of running injuries. By increasing impact forces on the forefoot and mid foot, "minimalist" runners may be subjected to increased rates of forefoot and midfoot injuries and plantar skin breakdown compared with shod runners. While cases of metatarsal stress fractures in "barefoot" runners have been reported (17), some researchers contend that the plantar surface of the foot resists perforation while providing sufficient protection to local bony structures (32). The elaborate sensory feedback on the plantar foot, which is able to tolerate substantial abrasive loads, should minimize any risk of skin perforation or pain associated with "barefoot" running (32,33,36).

Nonetheless, given these potential concerns, the transition to "barefoot" from a shod running style should

Table 2.
Pennsylvania State University Hershey BAREFOOT Essentials.

BAREFOOT Essentials	Explanation	Application
B. Body alignment	Proper posture is a key element of good running form. Positioning each joint correctly will help coordinate legs and arm motion, preventing wasted lateral energy.	Throughout your runs, try to keep your head level, back straight, and torso leaning very slightly forward. Focus on keeping your elbows at 90 degrees and driving straight ahead from your hips and shoulders. To ensure that your body is in correct alignment, watch yourself run in a mirror.
A. Air-ground awareness	Runners must know both how their bodies interact with the ground and how they reposition themselves in midair. The idea is not to tighten up and be a perfect running "robot" but simply to be conscious of how your body moves through the air and leaps off the ground with each step.	The push-off height naturally will vary among individuals but should remain consistent for a given individual during a run. Work to "soften" or relax your legs until your head bobbing is minimized as much as possible. In midair, keep your body centered without flailing arms or legs outside.
R. Reach softly	The phrase "reach softly" is meant to conjure up an image of a hand reaching out to touch a soft object. Barefoot runners hyperextend (pull up) their toes before touching the ground, leave them extended on contact, and flex them just before leaving the surface. This sequence of events gives a runner the best possible feel for the ground.	To replicate this feel in minimalist shoes, select a model that gives your toes good range of motion and your feet plenty of flexibility. Running barefoot allows the runner to maximally adapt to the running surface (pavement, grass, etc.), making changes in leg stiffness and ankle movement. Really try to feel the ground with your feet, and think about running as softly as possible.
E. Effortless energy	The gentle foot plants, smooth arm swing, stable head position, and soft legs involved in a barefoot technique should make running more enjoyable and give you more stamina during workouts.	When you get comfortable with the barefoot/minimalist technique, the running motion should feel easy and light. Think about "floating" across the trail, treadmill, or road instead of pounding away with each step.
F. Foot control	Recognizing the subtleties of how your foot moves during a run is a great step to improving form. The major goals are to reduce the heel strike and other detrimental running motions that conventional shoes allow for.	Ask yourself, what part of my foot is striking the ground first? Do my feet move similarly or does one of them rotate in/out more than the other? Focus on a short consistent stride, landing softly on the balls of your feet. If you feel yourself slipping back into old habits, acknowledge the slip and practice adjusting on the fly.
O. Optimize rest	A major problem for runners is knowing when and why to let the body rest. Running for back-to-back days can be brutal, especially if these runs are performed at high intensity (intervals or speed work), with a new shoe, or on a new surface.	Treat barefoot days as high-intensity days by following up with lower intensity ones (cross-training or conversation-pace runs). Your calves and shins and the internal musculature of your feet will get a harder workout than before and thus need more time to recoup. Make sure you nourish your body with adequate protein and carbohydrates after your workouts in order to speed muscle recovery.
O. Organized change	Change in technique takes time to master. The transition to proper barefoot running can frequently involve a sequence of "discoveries" of what it feels like to have run "softly" or with "bird steps."	Recognize that the transition will take each individual a different amount of time, and thus, it cannot be laid out perfectly in terms of days or weeks. Take an organized approach to mastering each drill. Then, link them.

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Table 2.
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BAREFOOT Essentials	Explanation	Application
T. Tune in	"Tuning in" ties all the other BAREFOOT Essentials together: recognizing body alignment, knowing how you interact with the air and ground, feeling the ball of your foot against the surface, noting the effortlessness of your stride, controlling foot movement, understanding when to rest, and allowing time for change.	If you feel any kind of pain during your runs, take note of it, and slow down or stop if necessary. If the pain feels like a severe or recurring injury, stop running and seek medical advice. Being aware of *how* you run will make you a better runner!

proceed cautiously to prevent injury. We have developed the BAREFOOT Essentials as a tool to assist runners in making this transition successfully (Table 2).

True "minimalist" running shoes should be lightweight (<8 oz) and highly flexible with an expanded toe box, no elevated heel (heel-toe drop <5 cm), reduced padding, and minimal artificial support (*i.e.*, air gel compartments) (34–36). All of these features allow the wearer of a minimalist shoe to "run barefoot" while avoiding acute puncture wounds, severe changes in surface temperature, infection, and other issues encountered in the unshod state. Runners wearing minimalist shoes, with practice, will approximate closely the "ideal" barefoot form with its characteristic softer impact, midfoot or forefoot strike pattern, and shorter, more frequent strides (2,11,19,24,35). Making this change in footwear and in associated running form potentially could reduce injury rates, a goal that modern running shoes have yet to achieve.

Conclusions

Despite a series of modifications to the modern running shoe, endurance runners continue to be plagued by overuse injuries. A "minimalist" running style, which features short strides and midfoot/forefoot strike, has been proposed to limit these injuries. While there is biomechanical evidence to support the ability of "barefoot" runners to disperse impact forces, no clinical study has demonstrated its superiority in reducing injury. If a transition to a "minimalist" style is contemplated, runners should proceed cautiously to avoid acute injury. The continued controversy over the efficacy of barefoot versus shod running and the associated impact on injury rates necessitates more outcomes-based research.

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