

## Running Injuries: Barefoot, Minimalist Shod and Shod Running

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### ABSTRACT

Participation in sports and physical activity provides physical, mental, social and economic benefits to both the individual and the society. Among the different types of physical activities, walking, jogging and running are the most popular ones. Since the latter part of the 20th century, running has become a popular sport around the world. In the last few decades, the number of people finishing a marathon has increased significantly. Accessibility and low participation costs are the main reasons for the increasing popularity of running. Barefoot running or waking is habitual for human race for millions of years. Earliest recorded evidence of footwear usage dates back to 8300 years ago and the invention of modern shoes came very recently around 1970s.

Recently there is an increased interest among the runners for minimalist shoe and barefoot running. Hence it is imperative know whether this trend is mere a fad or with evidence. There are difference in foot strike patterns for barefoot running (more of fore and mid foot strike) and shod running (more of hind foot strike). These differences causes change in load and injury patterns in lower limb especially for knee and foot.

The paper is a review comparing 3 categories of runners for the kinetics, kinematics, injury patterns, difference in foot muscle volumes and economy of running from scientific studies.

**Keywords:** Injuries, Running, Barefoot, Shod

Human race was habituated to barefoot walking and running since time immemorial. No known archaeological or paleontological evidence exists to suggest footwear usage by early members of the genus Homo (around 2 million years back) or by early Homo sapiens (around 200 000 years back) [1].

Earliest recorded evidence of foot wear usage dates back to 8300 years [2]. However, the modern running shoes were invented around 1970s [3]. Recently there is an increase in awareness among runners for barefoot running. In an electronic survey among 785 runners, majority (75%) indicated they were at least somewhat interested in running barefoot or minimalist shoes [4].

Members of Tarhumara Indians from Mexico's Copper Canyon routinely run hundreds of miles per week wearing sandals with tire-tread soles. These runners used a "barefoot style" characterized by a short stride, light steps, and footwear with minimal protection and maximal flexibility [5].

Since the latter part of the 20<sup>th</sup> century, running has become a popular sport around the world. There is a significant increase in the number of people finishing marathon in the last few decades. New York City marathon in 1976 is

considered as the first urban tour marathon [6]. In the last 40 years, millions of runners participated in the "World Major

Marathon Series" (events held in metropolises like Boston, London, New York, Chicago, Tokyo) with more than 40,000-50,000 finishers per each event [7]. Likewise, there is an increase in participation of women in marathon events. The first Olympic marathon for women held at 1984. The participation of women in marathon events markedly increased from 11% in 1980 to 34% in 1998. According to 2016 New York City marathon statistics, women make up 40% of participants [7].

Even with the technological advancements in developing modern running shoes, there is an observed increase in running injuries for runners. The annual incidence of running injuries is at a staggering 79%. The vast majority of these injuries involve the knee, leg and foot. The reported range of running injuries of the lower limb varies in different studies. Lower leg - 9.0% to 32.2%, Foot - 5.7% to 39.3%, Upper leg - 3.4% to 38.1% [5]. Knee is the most common

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joint involved in the leg and its incidence ranged from 7.2% to 50.0% [8].

Eighty Percent of running disorders are overuse injuries. These injuries happen due to the mismatch between the resilience of the tissues and running load. If the repeated stresses are below the tensile limit of a structure, it would result in positive remodeling of tissues, provided sufficient time is given between stress applications. If the stress is above the tensile limit and time between stresses applications are inadequate, ultimately it result in an overuse injury. Running is one of the most common sports that give rise to overuse injuries of lower back and the leg [8].

**RISK FACTORS FOR RUNNING INJURIES [9] (TABLE 1)**

Training errors such as running excessive distance, sudden change of training routines are found to be factors in 60-70% of all running injuries [10]. Runners with a high training frequency and/or running distance are being more susceptible to overuse injuries. It is found that running injuries are more for runners who have no running experience. Conversely, injuries also occur for experienced runners who run long distances, for longer period of time. There is only limited evidence for prevention of overuse running injuries by optimizing and personalizing training [8].

**Table 1.** Shows risk factors for injuries.

Systemic	Training Related	Health	Lifestyle
Age	Training frequency	Previous injury	Alcohol usage
Gender	Altered Terrain	Medical Issues	Smoking
Weight	Race distance		Cross training
Knee alignment	Running		
	Experience		
Flexibility	Shoe age and type		
Arch Type	Pace		

**DIFFERENCE BETWEEN SHOD, MINIMALIST AND BAREFOOT**

There are differences in foot strike patterns for barefoot and shod running. Barefoot endurance runners have more of forefoot strike (FFS) or midfoot strike (MFS) rather than rear foot (RFS). In shod runners rearfoot strike is more predominant pattern.

Barefoot and minimalist shoe runners have reduced stride length, increase stride rate and reduced foot contact time. There is less impact force in barefoot runners, minimalist runners and long distance runners [11].

In shod running, the RFS pattern changes into FFS with increase in speed [12]. The force generated on forefoot strike during running barefoot on hard surfaces are less than in rear foot strike in shod runners [3]. In habitual barefoot runners, higher plantar flexion angles resulting in forefoot or midfoot strike and a higher pre activation of plantar flexors [13]. The increased active pre stretch levels and reduced contact time enhances stretch shortening cycle of plantar flexors in barefoot running. This allows a better storage and restitution of elastic energy [14].

Systematic review of literature shows reduced peak ground reaction force with barefoot running [15]. Impact force,

shock reduction and reduced muscle activation intensity are found in Shod runners when they are trained in barefoot running for 16 weeks [16]. Another prospective comparison study of running injuries between shod and barefoot runners observed fewer injuries for barefoot runners [17].

According to a prospective study comparing barefoot and shod running, less knee and hip injuries observed for barefoot runners. The high torque in the knee in shod runners could be the possible reason for this finding [17]. Study among healthy women found that even a moderately high heel increases the peak knee torques [18]. OA knee patients could significantly decrease the dynamic loads at the knees by barefoot walking as it reduces the peak knee adduction moment by 12% [19].

Compared with traditional shod runners, minimalist shod runners showed a significant increase (10.6%) in Adductor hallucis muscle cross sectional area [20]. When a group of athletes used minimalist shoes during preparatory training, it found to increase the anatomical cross-sectional area of selected intrinsic and extrinsic foot muscles by 4-5% [21]. There is a significant increase in leg and foot muscle volume observed when habitual shod runners are transitioned to minimalist shoes [22].

Shod runners have higher torques at knee and hip compared to barefoot runners. This increase in torque is thought to be contributed by high heel and increased material under the medial arch in modern running shoes. As a result of increase in knee flexion torque, the demands put on quadriceps muscles are also increased. This causes an increase in the strain through the patella tendon which, in turn increase pressure across the patellofemoral joint. There is also an increased knee varus torque noted, which lead to a greater compression forces in the medial compartment of the knee [23].

Studies show that traditional shoe construction alters the load to that extent of increasing the injury risk. When shod runners are put on barefoot running, it found to reduce the injury risk. The greatest improvement in injury risk was noted in the knee. Barefoot running also improved the previous injuries of foot, ankle, hip and low back after starting the barefoot running program and majority (64%) of the runners did not experience any new injuries. Some authors strongly believe that prescribing running shoes based on arch type is incorrect and according their observations, there is no difference in injury rates compared with control group [23].

Runners with chronic plantar fasciitis found to have reduced overall plantar foot pain while using ultra flexible training shoes compared with traditional cushioned shoes [24].

Economy of running is also different between barefoot and shod running. At pace of 70% of  $VO_{2max}$ , barefoot running is found to be more economical than shod running both on treadmill and over ground. There is an increase in cadence, decrease in foot contact time and vertical displacement among barefoot runners compared with shod runners [25]. A 4 week simulated habitual running on 15 trained male athletes found to improve the running economy by around 7% compared to shod running [26].

In a meta-analysis after reviewing of 13 studies and 168 runners, Chung et al. [27] found running economy for barefoot and minimalist shoe are better than shod running. In shod runners, during heel strike, the lower limb comes to halt during impact, whereas the body continues to move across the knee. During the initial impact, the heel takes up about double or triple body weight. But in contrast, the Midfoot Strikers (MFS), the foot is in alignment with the hip and prevents heel from initial contact. The weight of the body is distributed through a larger surface area of forefoot thus reducing the overall force. It helps to allow the knee to work as a better shock absorber. When comparing the forefoot strikers (FFS), MFS found to have same force parameters [3].

Barefoot running has [28]:

- Reduced dorsiflexion of ankle at initial contact.
- Reduced knee flexion in midstance.

- Reduced work and moment at knee.
- Increased moment and work at ankle.
- Knee extension and adduction moments reduced by 9-12% due to the reduced knee flexion in barefoot running.
- Reduction of 24% of negative work done (work done in eccentric contraction) at knee.

Minimalist shoe as defined by a consensus group are shoes having thin flexible structure, low mass, low heel to toe drop, low stack height, minimal over all cushioning and absence of any kind of motion control design [29]. A recent study among habitually minimalist and shod runners found commercially available minimalist shoes not helpful in reducing the rate of loading than shod runners [29].

In their defense, the proponents of barefoot running argue that our ancestors ran for thousands of years without high-technology sports shoes, so human feet are adapted to run bare on the ground. The modern shoes we use now a days became available only very recently in 1970s [30]. The advantages for barefoot running are, low collision force, reduced running cost, increased perception of movement and increased muscle strength [30]. Habitually barefoot runners tend to use the forefoot strike pattern, whereas most of the shod runners use the heel strike pattern.

In forefoot or midfoot strikers the center of pressure trajectory goes backward after landing and subsequently goes forward, whereas in the case of rearfoot strikers, the center of pressure trajectory goes forward directly after landing. The forefoot strike results in decreased effective mass in the lower extremities and decreased collision force during running, which is believed to reduce injury rates for barefoot runners [30].

Majority of traditional shod runners (upto 95%) land on their heel (rearfoot strike-RFS) when they run on modern hard surfaces [31]. Approximately 5% land with a flat foot (midfoot strike-MFS) and 1% land on the ball of their foot (forefoot strike-FFS). Given that humans evolved the ability to run without the assistance of footwear, strike patterns during barefoot running likely represent our most natural form [31].

A 12 week transition program in simulated barefoot running could assist athletes seeking a more-forefoot strike pattern and “barefoot” kinematics, regardless of preferred footwear [32]. Habitually shod runners may be subject to injuries more easily when they run barefoot while maintaining their heel strike pattern [30].

Rearfoot strikers experience a reduced stride length, more plantar flexed position of foot at ground strike and reduced magnitudes in impact peak, while switching from shod to barefoot running. These results suggest that when barefoot,

even the rearfoot strikers ran similar to the midfoot/forefoot strikers group [33].

Systematic review on biomechanical differences between barefoot and shod running suggest barefoot running may be associated with positive biomechanical changes with regards to injury prevention [15]. A prospective comparison of running injuries between shod and barefoot runners by Altman, showed fewer musculoskeletal injuries per runner among barefoot runners [17].

Contrary to the popular perception, more than 50% of boys from high socioeconomic status preferred barefoot, according to a cross sectional survey among 714 secondary school boys in New Zealand [34].

## CONCLUSION

In conclusion, there is definite biomechanical advantage for barefoot runners compared with Shod running. There are fewer loads on joints with barefoot and less incidence of injuries. The intrinsic and extrinsic muscles of foot are more developed in barefoot runners than in shod runners. It is advisable to have a transitional training period for habitual shod runners before adopting for full time barefoot running. Minimalist shoes are not shown to be superior when compared with traditional shoes.

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