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Review Article

Physiotherapy Section

Barefoot Running: Myths and Realities of Barefoot and Shod Mechanics towards Implicating Running Related Injuries

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ABSTRACT

Modern footwear has changed in its role over the years from providing protection to controlling foot motion and stabilisation. However, Running Related Injuries (RRIs) continue to increase despite technological innovations in fabrication and design. As we evolve in our understanding of barefoot running, examining this pattern of running is worth giving attention to. Barefoot running changes the foot strike pattern to forefoot strike with reduction in stride length and impact loading. Also, barefoot form of running provides a greater proprioceptive challenge to plantar surface of the foot and increased energy conservation at the arches. The advent of new footwear trend in form of minimalist shoe is slowly gaining attention but it is presumptive to appreciate its benefits over barefoot running. The purpose of this review was to study the evidence regarding differences between shod and barefoot mechanics and how different footwear affords mechanical changes between them. Future directions on barefoot running mechanics and its progression are also suggested.

Keywords: Foot strike, Footwear trends, In-shoe mechanics, Proprioception, Running biomechanics

INTRODUCTION

Humans have been walking and running all these years and have evolved depending on the need of survival and the fact that survival was based on our ability to run and feed for ourselves [1]. Anthropological evidence also suggests that these changes in our ability to survive coincided with size of our brains growing bigger with dependence on fats and proteins. Prior to invention of various hunting instruments, Homosapiens had to catch their prey until heat exhaustion [2]. However, data on Running Related Injuries (RRIs) in early homosapiens is missing. Regardless of why running was pursued, running was started without shoes.

The most ancient types of shoes discovered are over 10,000 years. The construction and fabrication of these shoes was such that the only function it provided was protection to the plantar surface of foot. Running footwear have evolved significantly up until the 1970s when technological advancements into its fabrication and design introduced lighter material, an elevated heel, shock-absorptive midsoles for improved cushioning and motion control systems for better foot stabilisation [1,2]. The added features have also provided the shoe manufacturers with segmented marketing strategies to introduce shoes for comfort, injury prevention and correction of movement patterns [1].

However, a pertinent question still remains as why RRI continue to surge [1]. Undoubtedly, human evolution has brought about a change including but not limited to nutrition, environment and daily fitness regimes. It is speculated that running shoe wear has had a considerable impact in the way we run and walk now-a-days [3]. Proponents of modern running shoe support the notion of cushioning and motion control shoe to protect us from injury [4]. However, this has not translated to reduction in injury occurrence even when runners were matched to type of shoe and structure of foot [3-6].

Over the last decade, biomechanical studies have demonstrated running without assistance of shoe might lead to reduced injury rates [7]. However, a closer look at the scientific literature shows that a clear relationship between running shoes and injury rate is weak, heterogeneous and sometimes contradictory. Recent interests into studying effects of different footwear on running mechanics and performance has mixed reviews [8]. The aim of this review is to introduce an overview of differences in running mechanics between shod and barefoot running and differentiate the effects of different shoes on running mechanics. The review concludes with future directions to study this aspect of injury prevention. The literature used is based on a non systematic search of the MEDLINE and PUBMED database and focuses mainly on work published over the past 10 years.

SHOD RUNNING MECHANICS

Running shoe has changed over the years since the fabrication of first shoe in 1890s by J.W. Foster and Sons (Reebok, Canton, MA) [9]. Consisting of leather with spikes over forefoot, the shoe was quite popular for its design and innovative fabrication. In 1917, the first sneakers, the Keds Champions (Keds, Richmond, IN), were introduced made up of vulcanised rubber [10]. The first spiked running shoe customised to different foot type was introduced by Adi-Dasler (Adidas, Herzogenaurach, Germany) in 1925 [11].

The transition of running shoe into modern running shoe began with a cushioned heel by Asics Onitsuka Tiger, which was later bought by Phil Knight to the US in 1963 [11]. The trend continued when Knight left Asics to partner with Nike in 1972, leading to their own branding of cushioned shoe with the name, Cortez N [11]. As time passed, features like movement control and stability have constantly featured in the modern shoe. Specific to providing cushioning and support, the modern shoe now offers dual density midsole, elevated, cushioned heel, arch support, stiff heal counter with a host of other add-ons. These additional features also assist in foot function and reduce injury though the benefits of these technological innovations on injury prevention have often seen conflicting results [12].

Due to these advances, 75% of modern distance runners are typically Rearfoot Strikers (RFS) [13]. Elevated, cushioned shoe heel are often attributed to develop such patterns. Almost 24% of runners land with their first ground contact with a flat foot or Midfoot Strike (MFS). Just 1% are Forefoot Strikers (FFS) displaying first ground contact over ball of foot.

Foot strike patterns are often cited as one of the factors used for injury risk stratification in runners [14]. In addition, foot strike patterns are also influenced by running environment, coaching practices, footwear and body structure. Landing mechanics are extensively reported in the literature [14-16]. Landing with RFS has shown defined impact peak in the vertical ground reaction during ground contact just before the propulsion peak translating into high impact loading rates in early running stance [15]. This pattern predisposes the runner to develop injury. In contrast, FFS patterns attenuates this impact due to eccentric loading of posterior calf muscle spikes significantly reducing the injury susceptibility risk. The MFS patterns have reported to fall typically between RFS and FFS patterns [15].

Stride length is also affected by the type of foot strike pattern. FFS has shown shorter stride length with the foot being positioned close to the centre of mass of body [15-18]. This leads to reduction of moment arm of ground reaction force to lower extremity segments of hip and knee joints. Manipulating the step rate influences joint mechanics during gait with 10% decrease of stride length in RFS resulting in significant hip and knee joint moments, impact peak and loading rates [19,20]. Bone health is also benefitted with shorter stride lengths with reduction in tibial stress fractures, despite higher cadence [21].

A systematic review on understanding risk factors and sex differences for injuries in running cited wearing running shoe for more than 4-6 months to be associated with greater risk of sustaining injuries in women than men [22].

Shod Running Injuries

The multifactorial nature of RRIs makes it difficult to prognose such injuries. Overuse, repetitive phenomena and history of injury [22] are common aetiologies along with abnormal mechanics. Running malalignments like pronated foot, genu valgus and varied spatiotemporal kinematic running gait changes are frequently cited in literature [23]. However, impact transient forces with greater frequency of loading in RFS pattern have also been reported [24]. Also, training practices like infrequent high intensity bouts of running for exercise or performance increases the risk.

The RFS pattern is also associated with increased loading of anterior leg musculature with foot prominently placed in dorsiflexion at foot strike. Hypertrophy of these muscles and raised compartmental pressures lead to exertional syndromes [24]. Transitioning to Forefoot Strike Pattern (FFS) has shown extensive improvements in RFS runners with chronic compartment syndrome while improving running distance over one year follow-up. The study findings showed that transitioning to FFS significantly improved the chances of avoiding fasciotomy [25].

BAREFOOT RUNNING MECHANICS

Changes to barefoot running mechanics are widely reported in the literature [26]. In view of all the changes reported, running without shoes encouraging FFS pattern has been widely reported [27-31]. Comparisons between shod heel strike against barefoot heel strike has shown very high ground reaction load rates in the latter which is typically uncomfortable [7,27-29].

Barefoot running reduces stride length and increases cadence more than shod running with RFS pattern [19]. As previously reported, reduced stride length further decreases body load thus protecting the runner from impact related injuries. Ankle continues to assume plantaflexed position at landing in barefoot [19-21].

Barefoot running changes the overall joint mechanics across lower extremity. In support of this, barefoot runners are found to exhibit lower rear foot eversion during early stance when compared with shod runners [28]. The energy conservation strategy of medial longitudinal arch takes advantage with FFS pattern found with barefoot runners with increased vertical arch motion during load acceptance [31,32]. There are contrasting findings on running barefoot implicating fallen arches due to repeated loading of unsupported arches. At larger joints involving hip and knee proximally, changes to mechanics are more pronounced. Knee flexion, knee adduction and hip external rotation moments were decreased in barefoot running [31].

Although limited in scope, there are reports suggesting reduced proprioceptive in presence of any tactile barrier between either due to ageing or wearing of shoes [33]. Effects of wearing socks were seen and compared against barefeet for static balance control [34]. The study findings observed a greater static balance when standing barefeet [34]. Similar to wearing hand gloves, wearing socks filtered out important sensory input from the mechanoceptors in our feet. Measures of dynamic stability during single leg landing using dynamic postural stability index was found better in barefeet than in standing running shoes [35]. This also makes us believe that barefoot may also promote better ankle position sense [36]. These findings are to be seen with caution as powered studies in this aspect are currently lacking.

Minimalist Shoe-trending Now

In line with emerging evidence on barefoot science, various shoe manufactures have started working on "barefoot" or minimalist shoes. The most common ones are Vibram, Albizzate, Italy), Nike Free (Nike, Inc., Beaverton, Oregon), Saucony Kinvara (Saucony, Inc, Lexington, MA), and New Balance Minimus (New Balance, Boston, MA) [37]. Preliminary findings are promising for these new shoes though it is unclear if minimalist shoe may provide additional benefits against barefoot running.

In general, minimal footwear running assumes lack of cushioning will enhance the probability of soft landing. However, some results pointed the opposite. Willy R and Davis I reported that while running in Nike 3.0 (Nike, Beaverton, OR) footwear, participants landed with greater dorsiflexion and increased vertical load rates and tibial shock in comparison to standard neutral running shoe [38]. A similar lab based study by Lieberman DE et al., using Vibram five finger shoes, 10 of 14 participants exhibited RFS pattern at start of study [7]. Following six weeks of training, all participants were less dorsiflexed.

Empirical evidence suggests that runners do adjust their mechanics to land more softly, thus lowering the heel load on impact. This notion is also supported when runners have shown softer foot strikes when landing on hard surfaces [39].

Barefoot Injuries

Injury risks associated with barefoot running are believed to increase risk of injuries due to absence of any protective cushion at foot surface interface. However, this belief is least supported by strong evidence. Anecdotal testimonials are found in plenty sharing their experiences of being cured of their injuries following barefoot programs. In absence of any credible evidence on running mechanics, training patterns, most of this data is speculative for the cause of injuries associated with barefoot running.

Running barefoot on hard surfaces is suggestive of increasing loading to lower extremity thus increasing chances of injuries. Surprisingly, numerous studies have reported reduction in leg stiffness in response to landing on hard surfaces [40,41].

Damage to plantar surface of foot is undeniably profound with barefoot running. However, plantar surface can tolerate more than 300% more abrading loads than hairy skin on thigh [41]. Despite this, foot is exposed to cuts, bruises and abrasions when barefoot.

Transition to barefoot running or walking can often be detrimental in absence of an adequate period of transition or habituation. Any novel training system needs adaptation period to wean off from the tradition and acclimatise to new loading. It is essential that proponents of barefoot running keeps this in mind while designing training systems to allow leg and plantar muscles to affirm to the plantar sensations during barefoot running [33,41].

FUTURE RESEARCH

Effects and benefits of barefoot running are fairly limited in scope and implementation. Studies addressing biomechanical and physiological aspects are advancing our understanding of this novel training system. There is suggestion that barefoot running reduces impact transient forces, and improved kinaesthetic sense thus resulting in static and dynamic stability [41]. However, any specific injury patterns associated with barefoot running are still lacking. Potential areas of future studies may reflect on following questions:

1. What are potential benefits of barefoot running on improving foot and ankle muscle strength?
2. How to identify potential candidates for transitioning to barefoot running? Should structural deviations or history of RRIs be potential risk identifiers in runners?
3. What are best strategies for a mechanical transition from shod to barefoot running to minimise the risk of injury?
4. What injury patterns are more common with barefoot running?

CONCLUSION(S)

Modern running shoe has potential benefits from RRIs. However, their efficacy in preventing injuries lacks scientific support. Heavily cushioned and motion controlling shoe is proven to be unnatural and thus may be pivotal to high rate of injuries in modern runners. Vast number of studies have addressed acute biomechanical changes to barefoot running. However, the injury risk associated with barefoot running is still unknown. Support for paradigm shift on foot strikes, footwear and management strategies for foot pathologies is emerging. Statistically powered, large scale, prospective studies are needed to ascertain whether removing modern running shoe during training for recreational or any form of running truly gives us health related benefits.

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