Research Paper Review

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A Theoretical Perspective on Running-Related Injuries

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ABSTRACT

The etiology of running-related injuries remains unknown; however, an implicit theory underlies much of the conventional research and practice in the prevention of these injuries. This theory posits that the cause of running-related injuries lies in the high-impact forces experienced when the foot contacts the ground and the subsequent abnormal movement of the subtalar joint. The application of this theory is seen in the design of the modern running shoe, with cushioning, support, and motion control. However, a new theory is emerging that suggests that it is the use of these modern running shoes that has caused a maladaptive running style, which contributes to a high incidence of injury among runners. The suggested application of this theory is to cease use of the modern running shoe and transition to barefoot or minimalist running. This new running paradigm, which is at present inadequately defined, is proposed to avoid the adverse biomechanical effects of the modern running shoe. Future research should rigorously define and then test both theories regarding their ability to discover the etiology of running-related injury. Once discovered, the putative cause of running-related injury will then provide an evidence-based rationale for clinical prevention and treatment.

ANALYSIS

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Background Information

If you're a runner, chances are you've had a running related injury (RRI). Actually, runners tend to be at a relatively high risk of getting injured. One approach to preventing injuries that has been embraced by the mainstream running community is the prescription of running shoes based on foot type.

WRITER'S NOTE: We've all encountered the student working part-time in running shoe store. I was that kid! As a teenager I worked in a running shoe store and my pay was based on selling shoes. I didn't know (or care) about running injuries and biomechanics or any of the latest research on running. I needed to sell shoes. Prescribing running shoes based on foot type in order to prevent RRIs ('Running Shoe Theory' or RST) and following the claims made by the running shoe manufacturer was an easy and sure way to get sales. Unfortunately, the 'old' RST has never been adequately tested scientifically and is certainly a simplistic approach to tackling a very complex problem – see below.

In the last 40 years, the incidence of injuries has actually increased alongside the development of the modern running shoe (1). As such, the RST has come into question from many in the running community. Complicating matters further is the Barefoot Running Theory (BRT). This 'new' theory posits that barefoot running is more natural and potentially less injurious. However, just like the RST there is only a small amount of scientific evidence to support this new way of thinking.

We, as clinicians, and the running community in general have a big problem – two theories with minimal evidence to guide our clinical decisions. Gallant and Pierrynowski have written an elegant paper, which summarizes the evidence for both the RST and BRT, while underscoring how the 'new' theory addresses the problems of the 'old' theory.

SUMMARY

The "Running Shoe Theory" (RST)

The RST can be summed up in what is seen in a typical modern running shoe: a rigid heel counter to control motion at the subtalar joint with pronation control and elevated cushioned heel (PCECH) shoes which are prescribed after classifying an individual by foot type and arch structure. However, a somewhat recent systematic review demonstrated that no studies have evaluated the effects of running shoes on injury or performance (2). The gold standard in injury prevention still seems to be represented by wearing large, bulky shoes. All one needs to do is venture into any orthopaedic shoe store and you're likely to walk out with big, bulky, conventional shoes. Are our feet so inherently fragile? Do we really need to protect them in bulky, supportive shoes? Has the evolutionary design of the human foot been unsuccessful?

The two most common causes of RRI's stated by the RST are high-impact forces (kinetics) and abnormal subtalar motion (kinematics). The high-impact force relationship to RRI's was developed from a biomechanical perspective, which suggests that each tissue has a different injury threshold, which may be reached with either a high frequency or high stress (magnitude) of impact forces. There have been a number of recent studies suggesting that injured runners have greater vertical impact forces than non-injured runners (4-8). However, high-impact forces can be altered with small changes to one's running form, such as stride length, muscle control, cadence and foot strike pattern.

RST has also argued that running on hard surfaces increases impact forces. In fact, it has been shown that humans running on hard surfaces tend to land with less leg stiffness and, therefore, maintain the same peak ground reaction force due to body adjustments from muscle tuning in the locomotor system prior to landing (9-10). A further study also showed that there is no difference in vertical force or loading rate between runners with new and well cushioned shoes compared with old and poor cushioned shoes. Richards (2) went so far as to suggest that cushioning itself may cause more harm than good by diminishing proprioception and providing the runner with a false sense of security against high-impact forces.

Now let's take a look at abnormal subtalar motion and RRI's. During the first 25% of the stance phase pronation at the subtalar joint allows for the attenuation of impact forces and allows the foot to become flexible and adaptable. As the foot approaches midstance, supination occurs to allow the foot to act as a rigid lever and propel the body forward. Abnormal motion at the subtalar joint is proposed to consist of (predominantly) overpronation which may stretch the plantar ligaments and prolong the internal rotation of the leg, both of which may lead to injury. However, based on the research available it is clear that there is no consistent association between overpronation (or for that matter any type of aberrant subtalar motion) and RRIs. One systematic review stated that motion control footwear is effective at reducing the amount of foot pronation, but there was no evidence that motion control footwear is effective at controlling rotation at proximal segments – where many

of the RRI's occur (11). Therefore, if abnormal subtalar motion does not lead to injuries, then altering subtalar motion may be meaningless.

The "Barefoot Running Theory" (BRT)

The BRT supposes that the foot is a dynamic, flexible system that attenuates high impacts with the downward deflection of the medial longitudinal arch and is thus capable of avoiding injury. RRI's occur when the foot is required to function unnaturally, like that when put in PCECH shoes. The three most commonly cited adverse effects of PCECH shoes are: atrophy of the intrinsic foot musculature, diminished somatosensation, and abnormal gait.

Atrophy of Intrinsic Musculature

BRT supposes that the foot's arch is maintained by bones, ligaments and intrinsic musculature. Therefore, the intrinsic foot muscles need to be used regularly in order to be strong enough to support the foot's arch. BRT further hypothesizes that intrinsic foot musculature may atrophy in PCECH shoes and lead to RRI's. A PCECH shoe might treat the symptom (i.e. plantar fasciitis) by providing support for the medial longitudinal arch; however, it does not treat the cause (atrophy of the intrinsic foot musculature). BRT suggests that strengthening intrinsic foot muscles may spare the tissues (i.e. fascia) by giving it support during impact. One study found a significant increase in medial longitudinal arch strength among recreational runners encouraged to walk or run barefoot over a 4 month period compared with a control group (3). However, this study had a small sample size and lack of dosage regulation. No published studies have yet reported a reduction in RRIs as a result of increased intrinsic muscle action.

Diminished Somatosensation

The BRT also proposes that sensory feedback between the peripheral and central nervous systems is critical in the avoidance of injury. The sensory information in our feet while walking and running is provided by proprioceptive muscle receptors in the foot and plantar mechanoreceptors on the skin's surface. Interestingly, the skin mechanoreceptors provide a more precise sense of foot position because they are not influenced by previous muscle contractions. Therefore, exposure of the plantar skin's mechanoreceptors to the ground surface is critical for accurate feedback to function optimally and avoid injury. One study found errors in foot position sense increased by more than 4° when in the shod condition compared with barefoot (12). BRT suggests that modern running shoes have made runners vulnerable by diminishing sensory feedback without diminishing the injury-causing impact. Barefoot running provides the foot's plantar surface with direct sensory feedback. This information is used to properly position the foot, minimize forces, and activate muscular support. One study demonstrated that treadmill surface slope was significantly better estimated by runners when wearing a minimalist shoe than when wearing a standard cushioned running shoe (13). Opponents of this study mention that the generalizability to barefoot running is poor and that minimalist shoes may provide the runner with a false sense of security, allowing them to run at an intensity that the natural barefoot would not allow. It would make sense that somatosensation allows the body to carefully monitor and limit the intensity of a run to prevent chronic overloading of the tissues. However, there is limited evidence to support this theory at this point in time.

Abnormal Gait

BRT proposes that PCECH shoes may contribute to injury by facilitating an unnatural running pattern. PCECH shoes will typically promote a heel strike pattern in runners; which can lead to over striding and an unnatural running form. This can cause the runner to ignore the body's natural adaptive processes and lead to overloaded tissues, increased impact forces and subsequently increased RRI's. In contrast, the BRT suggests that these impacts can be minimized through several different mechanisms such as:

- Shifting from a rearfoot striking pattern to forefoot or midfoot striking pattern and reducing the initial impact force (14).
- Increasing the cadence (step frequency).
- Decreasing stride length (14).

- Landing on the ball of the foot below the fourth and fifth metatarsal heads.
- Running with a loose and aligned upper body.
- Decreasing the amount of peak pronation or calcaneal eversion (15).

DISCUSSION

The RST proposes high-impact forces and abnormal subtalar motion to be the cause of RRIs. Therefore, to prevent RRIs, it is recommended that runners use shoes that provide cushioning, support, and motion control. There is little high-quality research to support this practice, and some suggest these shoes may do more harm than good. Looking at the BRT's reasoning (i.e. atrophy in the intrinsic foot musculature, diminished somatosensation, and altered gait) taken alongside the little research available, they might be onto something! However, the jury is still out. Future research needs to rigorously define and then test both theories regarding their ability to discover the aetiology of running-related injury.

For the sake of completeness in this discussion, we should mention some important points not addressed in this paper. Trends and fads tend to come with bias. Even within research itself, bias will show up far too often. A simple online survey regarding barefoot running was posted on a variety of social medial websites. In the barefoot runner group, 68% experienced no new injuries and 69% had their previous injuries disappear. Many barefoot enthusiasts will boast that these results are validating. Unfortunately, enthusiasts and extremists tend to clog up the internet and are typically disproportionately represented. So are these results accurate? Perhaps, but we don't know for sure. There is no way of knowing.

Lieberman and his Harvard group showed a large reduction in the impact loading rate in habitual barefoot runners, who landed with a forefoot strike (16). While those who land on the forefoot when running without shoes experience a reduction in loading rate, there is a subset of people who were barefoot heel strikers and had a 7-fold increase in loading rate. This should be a cause for concern but Lieberman's research group, which are barefoot enthusiasts, failed to illustrate this important point. Some researchers suggest that half of runners asked to run barefoot will heel strike, which will put them in harm's way rather than reducing their RRI's. Can these runners naturally acquire a midfoot or forefoot strike pattern? Can it be learned over a period of training time? These answers are unknown at this time. There have also been several published reports demonstrating that transitioning to barefoot running is associated with many lower extremity injuries (perhaps there is a chance we have simply swapped one set of injuries for another set of injuries?) (17). Finally, a recently published critique of barefoot running provided a long list of biomechanical and training factors that have been linked to injury (18). Many of the factors interact with one another and it is difficult to tease out singular variables. It would require a large prospective study with thousands of people whose training habits are tightly controlled to get a meaningful answer.

After reviewing Gallant's publication, along with some of the literature on barefoot and shod RRIs, the one thing we can safely say is that the jury is still out. We do know that there is no evidence that supports traditional running shoes, with regards to RRIs, over experienced minimalist or barefoot runners. However, it is a little too early to say that barefoot running is the solution for eliminating RRIs and everyone should switch immediately. Some runners may benefit from barefoot running and some may not. The 'one shoe fits all' analogy certainly does not apply here. Minimalist or barefoot running could be an excellent addition to training and is enjoyable for many runners. We know repetitive activity can lead to injury, and running is certainly a repetitive activity! So mixing it up with barefoot or minimalist running will certainly challenge your system and may lead to injury prevention and/or improved performance.

Study Strengths / Weaknesses

One of the primary strengths of this theoretical review is that Gallant and Pierrynowski give a sound and in-depth overview of both the Running Shoe Theory and the Barefoot Running Theory. After reading this publication I can see the points-of-view from both camps and where they are coming from.

I feel that a significant weakness in this publication relates to the bias that is obviously apparent throughout the paper. Even though I strongly agree with most of what was written, I couldn't help but feel that this was more of an opinion piece rather than a balanced scientific approach to looking at the issue at hand.

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