A Review of Mechanics and Injury Trends Among Various Running Styles

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ABSTRACT

Context: Running related overuse injuries are a significant problem with half of all runners sustaining an injury annually. Many medical providers and coaches question how to advise their running clients to prevent injuries. Alternative running styles with a more anterior footstrike such as barefoot running, POSE running, and Chi running are becoming more popular. Little information, however, has been published comparing the mechanics and injury trends of different running styles.

Objective: The original purpose of this paper was to examine evidence concerning the biomechanics and injury trends of different running styles. Little to no injury data separated by running style existed. Therefore, we discuss the biomechanics of different running styles and present biomechanical findings associated with different running injuries.

Data Sources: English language articles published in peer reviewed journals were identified by searching PubMed, CINAHL, and SPORTDiscus databases. Nearly all of the studies identified by the search were observational studies.

Results: A more anterior initial foot contact present in barefoot or other alternative running styles may decrease or eliminate the initial vertical ground reaction peak or "impact transient," possibly reducing knee joint loads and injuries. A more anterior foot strike, however, may increase mechanical work at the ankle and tensile stress within the plantarflexors. Wearing minimal footwear may also increase contact pressure imposed on the metatarsals.

Conclusion: More research is needed to determine which individuals with certain morphological or mechanical gait characteristics may benefit from alternative running styles that incorporate a more anterior initial foot contact with or without shoes.

The popularity of running is at an all-time high with nearly 500,000 people in the United States completing a marathon in 2009.[1] Annual running injury incidence has recently been reported between 19% and 79%.[2] This large number of injuries has medical providers and coaches struggling to determine how best to advise their running clients to prevent injuries. Alternative running styles such as barefoot running, POSE running, and Chi running have enjoyed an increase in popularity recently. Proponents of these alternative running styles with a more anterior landing pattern claim that employing these techniques will reduce injuries. Little information, however, has been published comparing the mechanics and injury trends associated with different running styles.

OVERVIEW OF DIFFERENT RUNNING STYLES

Traditional Shod Running

A recent kinematic analysis of elite runners wearing shoes who participated in a half marathon indicated that 75% of the runners were heel strikers, 24% were midfoot strikers, and 1% were forefoot strikers.[3] When runners use a rearfoot strike pattern, the knee is relatively extended and the ankle is in relative dorsiflexion upon initial contact. As the ankle moves into plantarflexion, the knee flexes and the knee extensors act eccentrically to dampen the ground reaction forces. Traditionally shod rearfoot strikers often take long strides, characterized by a vertical displacement of the center of mass and an impact peak present at approximately 10% to 12% of the stance phase on the vertical ground reaction force curve (Figure 1).[4] Runners using a rearfoot strike pattern in bare feet or minimalist footwear have demonstrated greater initial vertical loading rates than shod heel strikers.[4,5] Runners using a rearfoot strike may require greater angular work at the knee[6] resulting in higher patellofemoral and tibiofemoral compressive forces[7,8] and possibly greater risk of knee injury than other running styles with more anterior footstrike patterns. Advocates of barefoot and alternative running styles report that initial heel contact running is a relatively new phenomenon associated with the development of the modern running shoes with thicker cushioned heels in the last 30 to 40 years. Prior to this, many believe the proportion of midfoot and forefoot strikers was much greater.

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14. ABSTRACT
annually. Many medical providers and coaches question how to advise their running clients to prevent injuries. Alternative running styles with a more anterior footstrike such as barefoot running, POSE running, and Chi running are becoming more popular. Little information, however, has been published comparing the mechanics and injury trends of different running styles. Objective: The original purpose of this paper was to examine evidence concerning the biomechanics and injury trends of different running styles. Little to no injury data separated by running style existed. Therefore, we discuss the biomechanics of different running styles and present biomechanical fi ndings associated with different running injuries. Data Sources: English language articles published in peer reviewed journals were identifi ed by searching PubMed, CINAHL, and SPORTDiscus databases. Nearly all of the studies identifi ed by the search were observational studies. Results: A more anterior initial foot contact present in barefoot or other alternative running styles may decrease or eliminate the initial vertical ground reaction peak or ?impact transient,? possibly reducing knee joint loads and injuries. A more anterior foot strike, however, may increase mechanical work at the ankle and tensile stress within the plantarfl exors. Wearing minimal footwear may also increase contact pressure imposed on the metatarsals. Conclusion: More research is needed to determine which individuals with certain morphological or mechanical gait characteristics may benefi t from alternative running styles that incorporate a more anterior initial foot contact with or without shoes.

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Alternative Running Styles

Barefoot running and other alternative running styles have gained recent popularity, leaving many health care providers with questions regarding the safety and appropriateness of these techniques for various running populations. In several publications, barefoot runners exhibited a more anterior midfoot or forefoot striking pattern, thereby avoiding heel strike.[4,9-11] A growing number of barefoot running advocates, teachers, and websites have provided barefoot running instruction since publication of McDougall's 2009 book.[12] Generally with habituated barefoot runners, stride length is shortened, stride frequency is increased, and the vertical displacement of the center of mass is reduced.[9,13,14]

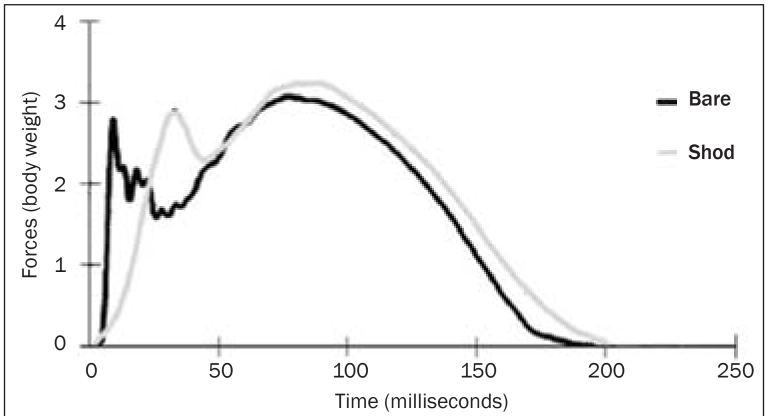

Figure 1. Vertical ground reaction curves of 1 representative person demonstrating a rearfoot strike pattern in bare feet and shod. Reprinted from De Wit et al[4] with permission.

One alternative running style that has gained popularity recently is the POSE method designed by Dr Nicolas Romanov.[15] This running strategy involves a midfoot to forefoot strike pattern that minimizes contact time with the support surface and focuses on picking up the feet and not pushing off the ground as vigorously.[15,16] Romanov claims that gravity causes the muscle system to absorb body weight on landing during POSE running, which then produces elastic strain energy. Romanov further describes that as the center of mass passes over the support limb, a gravitational torque occurs as extensor muscle activity ceases. The runner falls forward while the ground reaction forces decrease and vertical work against gravity is reduced. Romanov suggests that the foot is unweighted during terminal stance, as it is rapidly pulled from the ground by hamstring muscle activity to reduce lower-limb inertia and to catch up with the body. The focus on falling via a gravitational torque and pulling the foot from the ground effectively differentiates POSE running from more traditional running forms.

Another alternative running style that has recently gained popularity is Chi running. The founder of Chi running, Danny Dreyer, credits the origins of this running form to the discipline of Tai Chi.[17,18] This method of running is described as the alignment of body, mind, and forward movement. Runners are instructed to avoid heel strike and to land with a midfoot strike pattern. The body leans forward slightly, and the strides are shorter with a focus on relaxed legs. Dreyer recommends that runners discard more traditional heavily padded running shoes and use a more minimalist running shoe that involves thin sole material and limited supportive features.[17,19] In summary, barefoot, POSE, and Chi runners attempt to land with a midfoot or forefoot strike, take shorter strides with a greater frequency, and may demonstrate a reduced initial vertical ground reaction impact compared with traditional heel-toe shod runners. The original purposes of this review of literature were to examine additional evidence concerning the kinematics, kinetics, and injury trends associated with different running styles. Little to no injury data separated by running styles were found. Therefore, we discuss the biomechanics of different running styles and present biomechanical findings associated with different running injuries.

DATA SOURCES

English language articles published in peer reviewed journals were identified by searching PubMed, CINAHL, and SPORTDiscus databases. Key words used in this search included running, barefoot, POSE, Chi, kinematics, kinetics, injury, and running styles in various combinations. The authors included original research, meta-analyses, and review articles in the search. Only one randomized control trial was identified.[20] Nearly all of the studies included were observational studies. The search for manuscripts detailing aspects of Chi running in scientific peer reviewed literature yielded no results. The authors then resorted to using popular literature and website descriptions of the Chi running style.

RESULTS

Running Mechanics

Traditional Shod Running

For heel strikers (approximately 80% of shod runners),[3,9] the initial (impact) peak vertical ground reaction force at heel strike occurs during the first 10% of stance[21-23] or within approximately 25 milliseconds.[24] This force is passive in nature and the anterior-posterior component of this impact is generally considered a braking force with the heel strike anterior to the runner's center of mass. The second peak for the vertical ground reaction force occurs between 40% and 50% of the stance phase.[25] This force is more active as the runner pushes off the ground and the anterior-posterior component is more propulsive in nature with the runner's center of mass superior/anterior to the foot contact. Typical running peak vertical ground reaction forces for runners are between 1.5 and 3.5 times body weight.[25] Vertical ground reaction forces increase linearly with increasing running velocity[26] and increasing stride length,[27-29] and decrease with a faster stride rate or cadence.[30] Runners with a history of injuries may demonstrate greater initial peak vertical ground reaction forces than healthy matched runners,[22,23,31] however, this point has been refuted.[32]

Cushioned running shoes are commonly prescribed for runners with high arches and motion control shoes are often recommended for low arched runners who require pronation control. Cushioned running shoes may attenuate the ground reaction force better for high arched runners[33] and motion control shoes may control instantaneous loading rates better for low arched runners.[34] Increased resultant joint torques at the hip and knee have been observed in shod runners compared with barefoot runners.[7] Aside from the effects of footwear modifications, some runners may benefit from an altering their running style and learning to run with a reduced impact load or ground reaction force.[21] However, this has not been widely studied to date.

Alternative Running Styles

Most habitual barefoot runners choose to land with a midfoot or forefoot initial foot contact to avoid greater initial loading rates observed with heel striking in barefeet[4] (Figure 1). While most runners attempting to run in bare feet or minimalist shoes will convert to a more anterior footstrike, McCarthy et al reported recently on a sample in which 50% of runners continued to demonstrate a rearfoot strike pattern 2 weeks after changing to the Vibram 5-finger shoe.[5]

A toe-heel-toe or midfoot contact pattern used by barefoot runners and other minimalist shoe runners who use this landing strategy may decrease the vertical loading rates and initial passive peak vertical ground reaction force by 15% to 33% during the first 25 milliseconds of foot contact compared to traditional heel-toe strike patterns.[9,35] This reduction in initial peak vertical ground reaction force is accomplished by prolonging the time needed to decelerate the runner's vertical velocity after initial foot contact. By prolonging this period of time with a greater ankle range of motion,[10] the vertical ground reaction force is reduced as reflected by the impulse-momentum equation $F=m\times\Delta v/\Delta t$, where F=vertical ground reaction force, m=mass of runner, Δv=the change in vertical velocity from initial foot contact to the velocity of zero when downward motion stops, Δt=the time required to change the downward velocity to zero.

The period of time required to change a runner's downward velocity to zero (Δt) will likely be longer with a toe-heel-toe initial contact pattern than with a heel strike pattern. The initial vertical ground reaction force (F) will therefore be reduced. Another mechanism to decrease vertical ground reaction forces given a fixed mass would be to reduce the amount of change in velocity. This can be accomplished by reducing the vertical height from which the body's center of mass falls to the ground.[36] Essentially, limiting the vertical displacement of the center of mass prior to foot contact will reduce Δv. This is achieved by adopting running styles in which the runner glides forward more and bounces up and down less.

Little research has been conducted concerning injury trends that are associated with barefoot or other alternative running styles. Particularly of concern to some medical providers are metatarsalgia and other injuries related to foot contact patterns, particularly in bare feet.[37,38] Injuries caused by excessive contact pressures that are perpendicular to the foot-ground interface are governed by the equation

$$\text{contact pressure} = \text{contact force}/\text{contact area}$$

Wearing minimal footwear that has relatively thin sole material and no supportive features built into the shoe's construction may simulate conditions of barefoot running.[39] Running in bare feet or using minimal footwear may increase peak contact pressure, increase maximum ground reaction force, and reduce contact area of the foot, thereby increasing peak pressures imposed on the forefoot.[40,41] For a given ground reaction force, this reduction in contact area will significantly increase plantar contact pressure.[40,42,43] A 25% to 63% reduction in plantar contact area while running in bare feet[44] may counteract the 15% to 33% reduction in impact peak vertical ground reaction forces[9,13] achieved from using a toe-heel-toe strike pattern. This could result in potentially greater contact pressures on the more anterior portions of the metatarsals. High arched runners may experience greater risk of injurious plantar pressures in the lateral metatarsals,[45] while low arched runners may experience greater medial and lateral midfoot contact pressures under a variety of athletic conditions.[46] Concentrating the center of pressure on the midfoot[47] also increases the vertical ground reaction impulse stress (force × time) on the metatarsals. Previous investigators have reported greater stride frequency with a reduced stride length for individuals who run in bare feet or for individuals who run using a midfoot or forefoot strike pattern.[6,14] Greater peak axial strains and strain rates have been observed in the metatarsals than those in the tibia for barefoot running.[48] Increased stride frequency has been associated with reduced knee and hip loading,[36] however the shorter stride length and increased stride frequency associated with midfoot and forefoot strike patterns will result in more impacts per unit of time and distance, and potentially increased cumulative metatarsal strain compared with rearfoot strike running.

Another potential concern for injury is the increased moment requirement at the ankle joint associated with a more anterior initial foot contact. Runners who use a midfoot or forefoot strike pattern will require greater activation of the plantarflexors during early stance phase to effect the deceleration and then propulsive impulses.[13] This muscular activation may lead to increased mechanical work at the ankle[6,14,49] and additional tensile stress imposed on the plantar flexor muscles and Achilles tendon. Cole et al observed a greater magnitude and rate of loading in the ankle joints during the impact phase of barefoot running compared to shod running.[50]

Supporters of midfoot and forefoot strike running styles blame the initial peak ground reaction force and loading rate associated with a rearfoot strike pattern for increased strains that may injure the lower extremities.[9,31,51] While the initial passive impact peak ground reaction forces that occur at approximately 10% to 12% stance phase are greater for shod heel-toe runners, the midstance active propulsive vertical ground reaction forces may be greater for midfoot or forefoot strikers (Figure 2).[13,14] These greater active propulsive ground reaction forces have not yet been correlated with specific injury risk, but further investigation is warranted.

Figure 2. Vertical ground reaction force curve for the stance phase of gait displaying the initial impact transient (F_{Z1}) for shod runners and higher overall propulsive peak ground reaction forces (F_{Zmax}) in midstance for barefoot runners using a midfoot strike pattern. Reprinted from Divert et al[14] with permission.

Few scientific studies have evaluated the POSE running method. Dallam observed a decreased stride length, decreased vertical displacement of the center of mass, and increased oxygen cost when runners used the POSE method compared with traditional heel-toe running in a very small sample.[52] Arendse analyzed 20 individual runners who ran on an outside track, comparing traditional heel-toe running, midfoot strike running after 15 minutes of instruction, and POSE running after 7.5 hours of instruction.[6] Arendse observed decreased stride length and decreased vertical displacement of the center of mass when subjects ran using the POSE method. He reported greater initial vertical ground reaction forces with heel-toe running. Arendse also observed less eccentric angular work at the knee joint and greater eccentric angular work at the ankle joint when subjects ran using the POSE method. This reduction in angular work at the knee joint is often used to promote use of the POSE running method. Reducing knee loading at the cost of increased moment demands at the ankle joint, however, may lead to increased Achilles tendon or other ankle overuse injuries. Fletcher and Romanov also observed reduced stance time, decreased vertical and horizontal displacement of the center of mass, greater knee flexion angular velocity, and greater stride frequency in a sample of 8 runners after 7 hours of POSE running instruction.[53] Again, this increase in stride frequency may result in potentially increased cumulative metatarsal strain and total ankle joint work compared with rearfoot strike running.

The authors were unable to find any peer-reviewed biomechanical analyses of Chi running in the literature. In summary, POSE running, Chi running, barefoot running, and running with a forefoot or midfoot strike pattern have several commonalities. As shown in the Table, these include decreased stride length, decreased vertical displacement of the center of mass, and a possible shift from greater knee joint loading to greater loading at the ankle joint.

Injury Trends

Annual running injury incidence rates have been reported as ranging from 19% to 79%,[2] with the knee joint being the most commonly injured anatomic region among runners.[2,54] We were unable to identify any previous work separating injury trends by running style. With the majority of modern-day shod runners employing a heel-toe landing style,[3,9] previous injury reports may relate primarily to this running style. Potential causes of running related injuries and various mechanical observations associated with injuries in specific anatomical regions will be addressed. Finally, we discuss injury trends that may be related to wearing traditional running shoes or adopting alternative running styles.

Potential Causes

Many different potential causes have been suggested to explain running injuries. These potential causative factors can be organized into extrinsic and intrinsic factors. Extrinsic factors that may be related to running injury include running shoe age and training errors.[54,55] Training errors may be more associated with injury incidence than biomechanical factors.[55] Exposure to a high training load involving increased intensity, frequency, or running distance[55] without adequate rest may increase the risk of injury,[56] and modification of the training schedule may reduce the incidence of injury.[55-57] The effect of stretching on running injuries has not been determined.[55,58,59]

Intrinsic causes of injury include a previous history of injury,[2,54] increased runner age,[54] increased body mass,[54,60] foot strike characteristics,[23,25,31,61-63] and morphological characteristics such as excessive genu valgum,[64] pes planus,[31] and pes cavus feet.[63] Greater instantaneous and average vertical loading rates have also been observed in runners with a history of injury.[22,65]

Characteristics of various running styles.

	Traditional	Barefoot	Chi	Pose
Stride length	+	–	–	–
Stride frequency	–	+	+	+
Impact transient	+	–	unknown	unknown
Ankle moment	–	+	unknown	+
Knee moment	+	–	unknown	–
Vertical loading rates	+	–	unknown	unknown

+ denotes greater. – denotes lesser.
“unknown” denotes lack of research data.

Ankle and Foot Injuries

Particular characteristics present in subjects with a history of ankle and foot injuries were more years running, weaker plantarflexors, higher arches, and more inversion at touchdown.[59] McCrory et al suggest that plantarflexor insufficiency to control the eccentric phase of dorsiflexion may have contributed to the development of Achilles tendonopathy.[59] A more rigid foot may lead to “compensatory overpronation” that overstresses the Achilles tendon. Reduced tibial external rotation moment and more medial femoral rotation has also been associated with injury in a group of subjects with a history of Achilles tendonopathy.[61] Williams et al propose that this places the lateral gastrocnemius more anteriorly and the medial head of the gastrocnemius more posteriorly.[61] They hypothesized that this shortening of the medial head of the gastrocnemius may have resulted in changes in muscular stress at the musculotendinous junction that may have lead to the development of Achilles tendonitis. Another possible explanation may be that increased internal rotation of the entire lower extremity is associated with increased pronation, which passively stretches the Achilles tendon.

Increased dorsiflexion range of motion and greater instantaneous load rates were observed in a population of females with a previous history of plantar fasciitis.[31] Pohl et al state that the increased passive dorsiflexion range of motion is usually perceived as desirable.[31] They attribute this extra motion to the fact that these previously injured subjects were patients in rehabilitation where they commonly receive plantar flexor stretching exercises as part of their exercise prescription. Since this study was retrospective, the authors were unable to determine if the subjects had the additional range of motion prior to sustaining an injury or if it was acquired during the time the subjects spent in rehabilitation. The authors believe that greater instantaneous rates of loading may subject the plantar fascia to excessive stress.[31] Two groups of investigators have documented that greater pronation and leg length inequality were observed in other samples of plantar fasciitis patients.[63,66] Subotnick previously reported an association between limb length inequality and greater pronation.[67] Warren and Jones also observed greater dorsiflexion and less plantar flexion range of motion in a sample of runners with plantar fasciitis compared to controls.[66] Messier and Pittala observed greater plantar flexion range of motion in their sample of plantar fasciitis patients.[63] They hypothesized that excessive sagittal plane motion may increase the amount of time the runner can impart a propulsive force which may lead to excessive plantar stresses.[63] These authors also attribute greater pronation with greater midfoot stress on the plantar fascia for the injury.[63]

While the balance of running injury literature in the past 30 years assumes a rearfoot strike pattern while wearing traditional shoes, one recent case series detailed 2 marathon runners who sustained metatarsal stress fractures running in barefoot-simulating footwear reportedly adopting a more anterior footstrike.[38] Another recent military study reported reduced incidence of tibial and femoral stress fractures as the body adapted to the increased military training demands of several cycles of training, but no reduction in metatarsal stress fractures after months of infantry training.[68] This may suggest that the body responds differently to metatarsal stress compared to tibial and femoral stress.

Lower Leg Injuries

Several investigators have examined characteristics of individuals with lower leg injuries. Heel-toe landing styles have been associated with greater anterior compartment pressures than more anterior landing styles.[69] This could be due to a greater activation of the dorsiflexors during initial heel contact compared to a midfoot or forefoot initial contact pattern where greater activation of the plantarflexors has been observed.[13] In a recent case series, 2 previously rearfoot striking patients with chronic exertional compartment syndrome avoided anterior compartment release surgeries by adopting a forefoot striking pattern.[70]

Comparing runners with a history of tibial stress fracture to matched controls, runners with previous tibial stress fractures exhibited greater peak hip adduction and greater rearfoot eversion angles during the stance phase of running.[62,71] Milner and Pohl hypothesized that these forces may have induced a tensile stress on the posteromedial aspect of the tibia.[62,71] These authors also observed greater absolute free moment for individuals who had incurred previous tibial stress fractures.[51,62] Absolute free moment was defined as the torque acting between the foot and the ground at impact which may impose a torsional stress on the tibia.[62] Similarly, greater pronation and velocity of pronation were observed in subjects with a history of shin splints.[63] This increased pronation may increase the stress on the posterior medial tibia as increased stretching of the tibialis posterior imposes greater tensile stress on its proximal attachment site. Greater anterior-posterior braking force and vertical ground reaction forces were observed in another sample of tibial stress fracture patients.[72] Zifchock et al suggest that high peak tibial shock may lead to injury.[72] Creaby and Dixon, however, recently reported no differences in the magnitude of free moment, sagittal, or frontal plane vertical ground reaction forces observed in a small sample of military members with tibial stress fracture compared to matched controls.[32] In a recent systematic review,[73] Zadpoor and Nikooyan contend that greater vertical loading rates and not greater vertical ground reaction forces are more often associated with lower extremity stress fractures.[22,72,74,75] Additionally, no significant intrinsic risk factors were identified in a population of collegiate runners with exercise related leg pain.[76]

Knee Injuries

Multiple intrinsic risk factors have been associated with increased incidence of knee injuries, particularly patellofemoral pain syndrome. Lower extremity malalignment, particularly increased Q-angle and excessive pronation, have been identified as causative factors.[60,64,77,78] Genu valgus changes patellofemoral force vector alignment. Increased body weight and lack of hamstring flexibility may also be related to knee injury.[60] Increased body weight will increase the moment demands on the knee, which will increase the quadriceps and hamstring force production demands. Hamstring tightness may elicit greater knee extension force production, effecting a greater patellofemoral compressive resultant force vector from the knee extensors. Ferber et al recently observed greater peak rearfoot inversion moment, greater peak knee internal rotation angle, and greater peak hip adduction angle in a sample of 35 women with iliotibial band syndrome.[79] Abnormal hip mechanics such as excessive hip internal rotation or adduction possibly due to weakness in the hip abductors may also lead to undesirable knee mechanics and injuries.[80,82] Observed gender differences in strength and alignment may contribute to the running kinematic differences and higher overuse knee injury incidence observed in women.[80-83]

Foot Morphology

In a sample of military recruits, Cowan observed higher odds ratios for lower extremity overuse injuries in soldiers with the highest arches.[84] Messier also observed a similar trend with recreational athletes.[63] Higher arches were associated with greater lower extremity injury incidence in a different sample of female athletes.[85] Higher arches may be associated with rigid feet that do not promote shock absorption at initial foot contact. In a sample of 20 high arched runners, Williams et al observed more bony injuries and lateral injuries in the lower extremities (ie, 5th metatarsal stress fractures, lateral ankle sprains, and iliotibial band syndrome).[86] They also detected more medial injuries, knee injuries, and soft tissue injuries in a sample of 20 low arched runners.[86]

Traditional Running Shoes

In an effort to correct undesirable and possibly injurious mechanics, many healthcare professionals prescribe running shoes with extra cushioning to provide shock absorption, or motion control characteristics to limit pronation.[33,34] Cushioned running shoes may increase contact area and reduce contact pressures in cavus feet.[44,87] Likewise, motion control shoes may increase plantar contact area, reduce tibial internal rotation, and reduce plantar contact pressures in runners with flatter feet.[33,44] Recently, the practice of matching foot morphology to running shoe type has been questioned.[20,88,89] Even though undesirable mechanics have been prevented in laboratory settings by specific shoe selection and modification, no well-designed studies have demonstrated significant injury reduction by using this commonly used practice of shoe prescription. In the last decade, the results of several studies have demonstrated a correlation between injury and loading rates, and between injury and impact forces.[22,23,31] This growing body of evidence suggests that runners who have developed strike patterns that incorporate relatively low levels of impact forces and a more moderate rate of pronation are at a reduced risk of incurring overuse running injuries. [22,23,31]

Alternative Running Styles

Little to no research exists for injury patterns that may be associated with POSE, Chi, or barefoot running styles. Danny Dreyer claims that the braking forces of heel strike are responsible for many lower extremity overuse injuries.[17-19] The authors could not find any scientific manuscripts in any peer-reviewed journals to substantiate claims that Chi running is safer or superior to traditional heel-toe running mechanics in injury prevention or running economy. Dr Mark Cucuzella presented survey findings of 2500 Chi runners in 2008. Approximately 90% of the runners had favorable impressions of Chi running. Unfortunately, this survey was originally made available to approximately 25,000 people who had purchased Chi running materials and only 10% responded. Theoretically, the adoption of these alternative running styles may shift stress from the knee joint to the ankle joint,[6,8,50] potentially resulting in ankle and foot related injuries. These alternative running forms may be desirable if a runner has a history of knee injuries or knee osteoarthritis and is attempting to shift stress away from the knee joint. More research is needed to compare the mechanics of various running styles and to survey runners who have adopted these running styles for a sufficient period of time to assess the type and severity of injuries they are experiencing.

SUMMARY

Clinicians are often faced with questions from patients about running shoe selection and running style. Traditional shod heel-toe strike running gait has been challenged recently by individuals who advocate a more anterior initial foot contact, or minimal to no footwear which tends to force runners to make initial contact more anteriorly on the foot. Decreasing or eliminating the initial vertical ground reaction peak or "impact transient" has been cited as a potential method to reduce knee joint injuries or injuries in other anatomic regions. This theory requires further investigation to prove its injury prevention claims and to insure that runners who adopt a more anterior strike pattern are not merely increasing their risk for foot and ankle injuries.

Certainly more research is needed to determine ultimately which individuals with certain morphological or mechanical gait characteristics may benefit from alternative running styles that incorporate a more anterior initial foot contact with or without shoes. Controlled longitudinal studies are needed to assess the utility of adopting alternative running styles in an effort to reduce injury rates. Laboratory research comparing the mechanics of various running styles is needed to quantify internal force and moment demands of the various joints in multiple planes. Additional running shoe research is required with large samples of experienced runners to examine the potential effectiveness of matching running shoes to running mechanics and not merely foot morphology. Unbiased injury history surveys are also needed to evaluate the incidence of injury associated with various running styles.

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