The Running Atlas: A Literature Review of Running Form and Technique

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Abstract

Running is a form of physical activity that is prevalent and widely studied all over the world. People run for various reasons ranging from competitions to health-related motives. Although running is a common type of physical activity, it is considered a repetitive motion, stressing the body and causing a number of injuries such as Achilles tendinopathies, plantar fasciitis, and iliotibial band syndrome. Because running-related injuries are common, it is important to understand correct running form. Correct running technique encompasses the entire kinetic chain, involving the combined effects of an individual's musculature, skeletal, and nervous systems. Not only is correct running form important in order to minimize the risk of injury, but understanding the type of footwear best suited for an individual is significant in order to provide the best support, enhancing an individual's technique. Examining how the musculature, nervous, and skeletal systems coordinate and affect the kinetic chain will provide information on the most energy-efficient and least injury-prone running technique.

Introduction

Numerous reasons exist as to why people chose to run and can vary culturally. Runners from Kenya and the Tarahumara seem to be extremely talented at this particular skill which may be due to certain aspects of their lifestyle or cultures that are not widely practiced in the United States. Although certain cultural traditions are not commonly seen in the United States, individuals from the United States also participate in running, however, one of the main reasons that is not often seen in Kenya or with the Tarahumara is health-related. Running is one type of exercise that serves as a preventative measure for individuals suffering from cardiovascular disease and other diseases prevalent in the United States such as Type II diabetes (ACSM, 2014).

Form and the biomechanics associated with running is pertinent in order to understand the kinematics of an economical runner, as well as risks associated with common running injuries. Footwear is another factor to be considered in regards to running but has become a controversial topic within the running community. The type of shoe may also affect the running ergonomics and economy; however, numerous options of footwear exist so it is important to understand the pros and cons of certain types of running shoes. Because injuries are highly prevalent in runners, it is beneficial for runners to know how they can reduce their risk for injury. A combination of correct form, technique, and footwear can help increase running efficiency as well as decrease the risk of injury.

Cultural Differences

Many of the most accomplished Kenyan runners are from a tribe called the Kalenjin located in the Western Rift Valley which provides a high altitude training and living atmosphere (Marcus, 2014). The idea of living or training at high altitude is to increase the blood's oxygen-carrying capacity so that when someone trains or lives at high altitude and then races at a lower altitude, the body will have a heightened ability to deliver and use oxygen more efficiently (Wehrlin et. al., 2006)). Higher altitudes have "thinner air" meaning there are not as many oxygen molecules per volume of air. Because muscles require a certain amount of oxygen to contract and work, the body increases its production of red blood cells, which are the cells that carry oxygen. The release of the hormone erythropoietin triggers an increase in red blood cell production; therefore it allows the body to use more oxygen in higher altitudes, (Peterson, 2010) which is one theory as to why many Kenyan runners have been so successful.

Others have also theorized that because of the intense ceremonies required as a part of the transition into adulthood, these individuals become extremely tolerant of pain and learn to push through the toughest moments of the run. Warner, from National Public Radio interviewed a successful Kenyan runner by the name of Kipgogei, in which Kipgogei accounted events from his initiation ceremony. Kipgogei was required to crawl naked through stinging nettles, was beaten on the bony part of the ankle, had his knuckles squeezed together, and folic acid from stinging nettles was spread on his genitals (Warner, 2013). Throughout all of these tests and trials, he was supposed to keep a calm, stoic and unflinching demeanor or he would be considered weak by the other tribe members. People theorized that because the Kenyan men and women are put through a tremendous amount of pain during these ceremonies, it heightens their ability to tolerate tremendous amounts of pain, allowing them to push themselves harder during a marathon than some runners from other cultures (Warner, 2013).

In addition to cultural traditions, the shape of these individuals bodies, and possibly even genetics, play a role in their high rates of success. Genetics have been thought of as a possible factor, but there has not been much research or evidence that shows this as a high contributing factor; however, the body shape of these runners has been noted as somewhat different from other cultures due to their lengthy and thin ankles and calves. The legs act like a pendulum when running, so when less weight is on the pendulum, it is able to move more freely, delaying the onset of muscle fatigue and allowing for a more efficient running pattern (Warner, 2013).

The Tarahumara culture is portrays certain cultural differences than in many populated areas in the United States. These individuals live in a desolate, mountainous area, isolated from civilization due the rugged terrain of the Copper Canyons. They also many be thought of as hostile to the outside world. Media outlets refer to these people as the “Running People” because of their natural aptitude for running. The Tarahumara culture created the spike of interest in barefoot running in the United States because they won a number of races while running in rawhide sandals called Huaraches. These sandals only provide protection for the undersides of their feet from sharp objects on the ground. Because these shoes do not provide stability or cushion, like traditional running shoes commonly seen in the U.S., the Tarahumara people were essentially running barefoot (McDougall, 2009).

Another idea, proposed by Christopher McDougall, as to why these individuals can run so fast for such long distances is because of the cohesiveness of their culture. “The Tarahumara are actually an extraordinarily egalitarian society; men are gentle and respectful to women, and are commonly seen toting infants around on the small of their backs, just like their wives (McDougall, 2009, p. 73).” These people tended not to view running as a competitive race in which the only outcome that mattered was winning, but cared more about the journey, finding their passion, and enjoying life. In the Tarahumara’s eyes, “racing doesn’t divide villages; it unites them (McDougall, 2009, p. 75).” Based off of ideas of Dr. Joe Vigil, Christopher McDougall presents the idea that the next big step in running will be determined by character rather than science. “It was compassion. Kindness. Love (McDougall, 2009, p.92).”

The United States is home to many people who also enjoy running for a number of different reasons. A blogger, by the name of Scott Gillum, emphasized the idea that running can give a person a sense of accomplishment. He stated, “My approach is to choose events I’ve never done, and to usually do them alone, because it intensifies the fear factor…along with the fear and stress, I know there is a heightened sense of accomplishment” (Gilum, 2013). Other reasons people like to run may include, running for a cause or to raise money, prevention and/or to improve health, weight loss, appearances, stress relief, to meet new people, and to be able to eat more. All of these reasons provide people with motivation to be active in the United States, whereas, for the Kenyans and the Tarahumara, it is possible it may be linked to cultural traditions that they have known growing up versus in the United States where people are not accustomed to running ten miles to get to school every day, or even think of it as enjoyable.

“It’s not about the cards you’re dealt, but how you play the hand.”- Walter Boltz. One of the main differences between the U.S., Kenya, and the Tarahumara is the idea that individuals in the U.S. may be more inclined to run for health reasons, which makes sense seeing as cardiovascular disease is the leading cause of death in the U.S. and exercise is one way to reduce the risk of cardiovascular disease. Atherosclerosis is a common cause for cardiovascular disease and is essentially the buildup of plaque in the arteries. Plaque buildup is caused deposits of cholesterol, fat, calcium, and other substances found in the blood on the epithelial of the vessel. As people age, plaque buildup occurs and hardens and creates a narrowed vessels, increasing blood pressure and the likelihood of developing a thrombus or embolism (“What is atherosclerosis?” 2015). Cardiovascular disease also includes diseases such as coronary artery disease (CAD), peripheral artery disease (PAD), arrhythmias, and hypertension. These diseases and disorders increase the risk for a myocardial infarction or heart failure.

Although the specific cause of atherosclerosis is not known, certain risk factors for cardiovascular disease do exist (“What is atherosclerosis?” 2015). These include age, family history of heart disease, dyslipidemia, pre-diabetes, hypertension, smoking, obesity, and sedentary lifestyle (ASCM, 2014).

Like mentioned above, exercise is one way in which to decrease someone’s risks for cardiovascular disease. Exercise and blood pressure go hand in hand and have an inverse relationship, meaning that as an individual increases the amount of physical activity, chronic high blood pressure may decrease (ACSM, 2014). Exercise causes increased blood flow to the tissues making the heart work harder during exercise, ultimately creating a stronger more efficient heart. Exercise also increases the body’s metabolism to help decrease low density lipoprotein as well as lose weight to decreasing obesity and the risk of cardiovascular disease, as well as other diseases related to obesity such as Type II diabetes (Garber, 2011). Although it may seem easy to jump up and go for a run, it is important to note that it takes time and consistency to see results and improvements that can help decrease an individual’s risk for cardiovascular disease. The minimum recommended amount of physical activity for adults is 30-60 minutes per day of moderate activity on five or more days per week or

20-60 minutes of vigorous activity per day on three or more days per week. “Regular, purposeful exercise that includes major muscle groups and is continuous and rhythmic in nature is recommended.” Running is an example of a type of activity that fulfills these requirements and is one reason why many people choose to run (Garber et. al 2011).

Form

Running form is essential for novice as well as expert runners because applying correct running techniques can help reduce the risk of injury as well as increase running efficiency. Starting at the top of the body, the head should be in a neutral position, aligned with the spinal column, and the eyes should be facing forward looking toward the horizon (Hahn, 2015). The shoulders should be relaxed and the arms should fall slightly inside the line of the shoulder without crossing the midline of the body. As the arms swing anteriorly and posteriorly, the torso rotates at the thoracic column, allowing for adequate arm swing. If the shoulders were to remain square, it would require an individual to force the arm back rather than using the momentum generated from the thoracic rotation. Often times, when an individual forces the elbows backwards, it causes the elbows to angle outwards like chicken wings (McGee, 2013). When arm swing is altered, it decreases running efficiency because the body is not able to coordinate through the kinetic chain properly. It can create core and pelvic stability issues which can then lead to altered lower body kinematics, ultimately effecting how efficiently the body is able to use energy and increasing an individual’s risk for injury. In a study conducted by Pontzer et al. (2008), researchers found that when arm swing was resisted, shoulder and head yaw increased, meaning that arm swing helps to act as a mass damper, decreasing shoulder and head rotation, and helping to conserve energy.

Running is a repetitive motion composed of multiple gait cycles. One full gait cycle is composed of a swing and stance phase. Like the name sounds, the swing phase is the period when the “limb is in the air and moving forward” (Wallman, 2009). During the initial swing, “the thigh begins to move forward” once the foot leaves the ground. Midswing happens when the “thigh continues to advance as the knee begins to extend” and the foot clears the ground (Wallman, 2009). Terminal swing is the last phase in the swing phase and is observed by knee extension just before initial contact. The stance phase starts when the foot makes initial contact with the ground until the toe leaves the ground. After initial contact, the weight is “transferred onto the outstretched leg, which reacts to absorb the impact of body weight by flattening the foot” and is called the loading response (Wallman, 2009). It is important to note that because several strike patterns exist, the foot many not initially contact the ground with heel. If an individual uses either a midfoot or forefoot striking pattern the “heel strike” phase will be the point at which any part of the foot makes initial contact with the ground. The midstance phase is when the weight of the body shifts from the back of the foot towards the front and the body weight is centered over the single limb. Terminal swing is the last phase during the stance phase in which the body weight moves over the metatarsal heads and ends when the “contralateral limb [makes] initial contact with the ground” (Wallman, 2009).

Moreover, the hips serve as the center of mass so when an individual runs with slouched posture or excessive spinal flexion or extension, the pelvis will tilt posteriorly or anteriorly, creating undue pressure on the lumbar spine (Novacheck, 1998). Ideally, the pelvis should remain relatively neutral however, some rotation is necessary in order for the legs move to move anteriorly and posteriorly, propelling the body forward while avoiding any additional stresses that may be allocated on the spine (Wallman, 2009). During the second half of the swing stage and first half of the stance phase, the hamstrings and hip extensors coordinate to extend the hip. The hamstrings play an important role while running because they not only serve to concentrically extend the hip, but eccentrically slow down the momentum of the tibia prior to initial contact. During the late swing phase to midstance, the quadriceps contract in preparation to absorb the shock from the ground impact. Whereas, during mid-swing phase only the rectus femoris is contracting, keeping the hip flexed and reducing posterior tibial movement when the knee is flexed helping to propel and swing the leg forward (Novacheck, 1998).

Because both the hamstrings and the Rectus Femoris are biarticular muscles, they help to absorb energy during the stance phase. In the second half of the swing phase the hamstrings contract to extend the hip and flex the knee which creates an extensor moment at the hip and flexor moment at the knee. Because the hamstrings create a moment at the knee opposite of the actual knee movement, the hamstrings essentially “absorb” the energy at the knee and transfer it to the hips. However, the shortening of the hamstrings is minimal so as a whole, the hamstrings do not necessarily absorb or generate energy but instead merely transfers the energy from the tibia to the pelvis and vertebral column where the energy is then absorbed. This same mechanism can also be seen in both the gastrocnemius as well as the rectus femoris when transferring energy from the foot to the tibia (Novacheck, 1998).

Furthermore, the knee is another important joint when analyzing running technique. The knee is essentially a hinge joint between the femur, tibia, and fibula but also allows minimal rotation between the femur and tibia. The patella, or the kneecap, sits anterosuperior to the tibiofemoral joint and is connected to the tibia by the patellar tendon. The anterior cruciate ligament (ACL) runs from the anterior tibial plateau to insert on the lateral femoral condyle. The ACL helps to prevent hyperextension and excessive lateral and medial rotation of the tibia, however, its main purpose is to help decrease the amount of anterior translation of the tibia on the femur and help stabilize the knee joint (McKinley & O'Loughlin, 2012). The posterior cruciate ligament (PCL), runs from the medial femoral condyle to the tibial plateau and helps to prevent posterior translation of the tibia relative to the femur (McKinley & O'Loughlin, 2012). On the lateral compartment of the knee the lateral collateral ligament (LCL) originates on femur and inserts on tibia and provides resistance against varus forces. The medial collateral ligament (MCL) runs on the medial aspect of the knee originating from femur and inserting on the tibia and provides resistance against valgus forces. A combination of these ligaments as well as the muscles surrounding the knee joint provides support and stabilization to the knee during lower body movements (McKinley & O'Loughlin, 2012), however people who run with a valgus collapse, or an inward tilting of the knees while the feet remain shoulder width apart, may be putting more pressure on the MCL.

Accordingly, if the torso is in a neutral, slightly leaned forward position, it will allow for more accurate foot placement (Hahn, 2005). If the spine does have increased flexion or extension, the center of mass will move posteriorly or anteriorly, transferring the body's weight onto the heels or toes, respectively (McGee, 2013). Using an imaginary arc below the feet can provide a reference point for feet placement; however, keep in mind that arc length differs from person to person so a shorter person will have a shorter arc than a taller person. When using the arc technique, the feet should not be too far in front or too far behind the arc of that arc. Ideally, if the torso is slightly leaned forward, the feet should contact the ground in front of the body directly under the center of mass (Dichary, 2012). Generally, an individual with a "tighter arc" will be a more efficient runner than someone who has a larger arc, however, as speed increases so does the size of the arc, meaning that the faster an individual runs the longer the stride length. Although the average cadence should fall around 180 strides per minute, many people over-stride and fall into the range of 90-120 strides per minute which may decrease running efficiency (Courance, n.d.).

Additionally, three main striking patterns exist: heel strike, midfoot strike, and forefront strike. Heel striking occurs when the heel is the first part of the foot to make contact with the ground. Forefront striking occurs when a runner lands on the ball of the foot whereas, midfoot striking is when the runner strikes the ground with the arch of the foot first. In a midfoot striking pattern, the heel does make contact with the ground but the weight of the load is carried over the medial aspect of the foot instead of the heel. Contrastingly, forefront strikers land with greater plantarflexion than a heel striker which results in greater concentric anterior tibialis activation during the terminal swing phase in a forefront striking pattern. Because heel strikers make initial contact with greater dorsiflexion there is greater anterior tibialis activation before contact and when runners switch from a heel strike pattern to a forefront or mid-strike pattern there is greater anterior tibialis activation during the stance phase as well (Yong et. al., 2014). At initial contact with the ground, in a midfoot striking pattern, ideally the shin should be perpendicular to the ground. Unfortunately, many times an individual will rely heavily on the gastrocnemius and soleus muscles as well as the Achilles tendon during a mid-strike pattern because the foot initially contacts the ground too far forward on the toes, causing the shin to land at an angle greater than ninety degrees to the ground. This creates excessive loading on the calf, overloading the Achilles, and putting someone at higher risk of developing an Achilles tendon injury. Also, because the foot is in a plantar flexed position during initial contact relative to the toe-off phase, there is a wider angle between the foot and shank. Due to this larger angle and increased reliance on the distal aspect of the foot, residual pain in the distal aspect of the foot is not uncommon. Then, as the toes push off the ground, the movement pushes the body upward; however, a person is more efficient when the movement is forward instead of upward. During a mid-strike pattern, if foot is parallel to the ground the shin is more likely to swing through perpendicular to the foot. When the foot lands parallel to the ground and the shin perpendicular to the foot, the force is not isolated to the distal aspect of the foot but instead is able to dissipate over a larger surface area, decreasing the amount of load the calves bear (Gonser, 2013). This allows the ground reaction force to push up through the foot, directly transferring the energy to the calf muscles to propel the body forward (PegasusRunning, 2014).

Correspondingly, research suggests that running longer distances at an increased cadence, adopting a midfoot striking pattern may be more efficient and easier on the joints than a heel strike pattern. A midfoot strike pattern allows for a lighter landing because the lower leg muscles can gather the spring needed to propel the body forward; whereas, a heel strike pattern tends to cause the heels to pound the ground, creating more forces on the joints (Giandolini et. al., 2013). With a mid-strike or forefront striking pattern, the energy stored in the Achilles is more usable because of the decreased angle between the ground and foot. Therefore, the energy is able to be used immediately once the foot hits the ground. Landing on the midfoot not only causes greater lower limb muscle recruitment, aiding in a lighter landing, but also allows the forces to disperse over a larger surface area. On the other hand, a heel strike pattern, the force is driven up mainly through the heel into the knee and vertebral column (G. Sewczak-Claude, Feb 25 2016).

Improving Running Form

Core stabilization is essential for correct running form because proper stabilization aids in decreasing extra body movements while running (Dicharry, 2012). Because of the sedentary lifestyle many people live today, gives cause to the decreased core stability in many individuals. Countless people today spend eight or more hours a day sitting behind a desk which can create postural issues such as increased spinal flexion and rounding of the shoulders. Weak muscles that contract too late or that do not contract at all when needed contribute to many running related injuries. It is important to note that many of the common abdominal exercises, such as sit-ups or crunches, are dynamic exercises which target larger muscles; whereas stabilizer muscles are smaller and deeper which require static exercises in order to be targeted (Weil, 2010).

These deeper stabilizer muscles include the transverse abdominis, multifidus, the pelvic floor muscles, and diaphragm. The transverse abdominis runs horizontally around the lower torso like a “corset” and contracts in anticipation of movement to help maintain posture. The multifidus are small muscles that run from the transverse processes to the spinal process of the vertebrae. These muscles help to maintain rotary stability through small postural movements (McKinley & O’Loughlin, 2012, p. 342). The pelvic floor muscles lie deep within and around the pelvis and serve to stabilize the surrounding joints and support pelvic organs (McKinley & O’Loughlin, 2012, p. p.348-351). When running, the stabilization of the pelvic joints is important in order to maintain a neutral posture.

Additionally, the effect of elastic recoil on the muscles and Achilles tendon is important to consider in regards to postural stabilization. Postural stabilization is the integration of information from the visual, somatosensory, vestibular, and musculoskeletal systems to maintain the body’s position in space (Alberts et. al., 2015) and is important to enhance elastic recoil Elastic recoil is the idea that the body can use the impact energy to propel the body forward (Dicharry, 2012). When the foot makes initial contact with the ground, the muscles and tendons are at their most elastic which acts as springs to propel the body forward (PegasusRunning, 2014). Elastic recoil helps to keep the torso stable and correctly aligned, allowing for enough motion to get the leg behind the body and enough strength and power of the glutes to drive the body upwards and forwards (Dicharry, 2012).

Because running is a highly repetitive movement, it generates large forces in which the joint and soft tissue mechanics before and after ground contact determine the amount of a force present. As the foot makes contact with the ground, the forces are transferred up the kinetic chain, progressively dissipating as the joints and soft tissues absorb the forces. During ground contact the force is transferred from the foot up through the ankle to the shank structures, particularly the Achilles tendon, gastrocnemius, and soleus. The Achilles tendon is the largest and most powerful tendon in the body and is a major contributor for transferring these forces for efficient running (Mark, 2011). The Achilles tendon runs on the posterior side of the lower limb inserting on the calcaneus and originating from the soleus and gastrocnemius. The gastrocnemius is the largest, most powerful, posterior calf muscle that gives propulsive forces and allows for locomotion (Malvankar & Khan, 2011). Because the Achilles tendon is one of the first primary transferring structures, it receives a load of as much as six times an individual's body weight. When the foot makes contact with the ground, the Achilles stretches and stores potential energy, which is then used as the foot pushes off the ground, driving the body forward into locomotion. Postural support from the lower limb is mainly a result of the soleus which helps to maintain an upright position and because the soleus inserts on the Achilles tendon, the Achilles tendon also becomes important for postural stabilization (Malvankar & Khan, 2011

Another aspect of core stabilization to take into consideration is the effect is has on the "pendulum". Essentially, the pendulum is the anterior and posterior movement of the legs, much like the motion of an actual pendulum. If a pendulum was manually moved from its normal rhythm, the pendulum would react to the new forces, altering the original motion. Similarly, different postural positions can affect the pivot point of the pendulum. For example, if the lumbar curve increases in concavity, the center of mass moves posteriorly resulting in foot placement that is further out in front of the center of mass. In this example, not only has the pendulum's movement changed, but more energy is absorbed that is not able to be transferred through the kinetic chain. In order to keep the lumbar curve in a neutral position, core stability must be adequate (Dicharry, 2012).

The muscles surrounding the knee also play an important role in knee function as well as stability. On the anterior compartment of the thigh the main muscles that provide function to the knee is the quadriceps femoris which is the most powerful muscle in the body. This muscle is a knee extensor agonist and is composed of four heads: the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius. This muscle is an extremely important muscle because it helps to extend the knee when taking a step or standing up. While running the rectus femoris works with the iliopsoas to flex the hip during the swing phase. On the posterior compartment of the thigh are the hamstrings which are the antagonists of the quadriceps femoris meaning that they are the agonist for knee flexion. The posterior muscles of the crural region that help to weakly flex the knee are the gastrocnemius, plantaris, and popliteus.

The foot is composed of twenty-six bones, thirty-three joints, and over one hundred muscles, ligaments, and tendons (Healthline Medical Team, 2015). As mentioned above, the muscles of the lower limb that help invert, evert, plantarflex, and dorsiflex the foot and these muscles are called extrinsic muscles, whereas the muscles within in the foot are called intrinsic foot muscles are responsible for smaller motor control tasks such moving each digit (McKinley & O'Loughlin, 2012, p.385-391).

Valgus collapse is a common characteristic in many runners, especially in women, that can lead to injury. A Valgus collapse is when the knees are in an adducted and internally rotated position. Due to the wider alignment of the female pelvis, the femur can have a natural valgus angle increasing the likelihood of female runners to run with valgus collapse. Although the female pelvic alignment may make it more likely for women to have a valgus collapse, it is still a common error that may lead to injury in both men and women (Contreras, 2013). Pain on both the medial and lateral sides of the knee is not uncommon in an individual who runs with valgus collapse. Because the knees are adducted and internally rotated, the medial side of the joint capsule is expanded and the lateral side of the joint capsule is compressed. Both positions of the joint capsule are considered abnormal and can result in pain, especially considering an individual takes thousands of steps in one run. It is important to keep the knees aligned under the hips to avoid valgus collapse; however, several causes of valgus collapse exist that may require additional training to correct (G. Sewczak-Claude, March 29, 2016).

Valgus collapse may be caused by weak or uncoordinated firing hip abductors which are located on the lateral aspect of the hip and adductors which originate on the medial side of the hip. If an individual presents with weak hip abductors, the femur will tend to adduct, or fall in, because the abductor muscles lack the strength required to maintain a more abducted position. When the abductor muscles are weak, it requires the adductor muscles to overcompensate, strengthening the adductors and decreasing the functionality and use of the abductor muscles. If this adductor dominance is not corrected, an individual is at greater risk for injury due to the improper alignment of the skeletal structures and uncoordinated kinematics. Because the femur articulates with the pelvis, having adequate core and hip stabilization is essential when running. Working to strengthen the hip abductors along with pelvic and core stabilization exercises is recommended to help reduce the risk of injury. (G.Sewczak-Claude, March 29, 2016).

Injuries

Plantar Fasciitis

Plantar Fasciitis is a common overuse injury in runners associated with inflammation of the plantar fascia and commonly manifests as pain in the inferior heel. Often time's people complain of pain in the mornings or after sitting for longer periods of time. Because the foot rests in a plantar flexed position, the plantar fascia shortens so when an individual takes that first step after being sedentary for long periods of time the foot becomes dorsiflexed. This stretches out the plantar fascia causing inferior heel pain. The pain tends to lessen once the individual becomes more active, however, the pain may return later in the day after the amount of weight-bearing activity increases. Almost always the Achilles tendon, and subsequently the gastrocnemius and soleus will also be tight if an individual has been diagnosed with plantar fasciitis (Buchbinder, 2004).

The cause of plantar fasciitis is not completely understood and is thought to be multifactorial. Some of these factors include “obesity, occupations that require prolonged standing, pes planus (excessive pronation of the foot), reduced ankle dorsiflexion, or heel spurs” (Buchbinder, 2004). Because plantar fasciitis is common among runners, it is also thought that it may be caused by “microtraumas” which can occur with repetitive movements. Several risk factors have been associated with microtraumas such as “running excessively (or suddenly increasing the distance run), wearing faulty running shoes, running on unyielding surfaces, and having cavus (high-arched foot) or a shortened Achilles tendon.” (Buchbinder, 2004).

Numerous treatments for plantar fasciitis are available and range from icing, heating, stretching, using orthotics, and using night splints to surgery for more severe cases. Although there is a multitude of modalities that can help treat plantar fasciitis it is generally also recommended to use conservative treatments such as “decreasing the amount of running, stretching the calf and ankle muscles, avoiding flat shoes, and even using over the counter arch supports” (Buchbinder, 2004).

Achilles tendinopathies

Achilles tendinitis is another common overuse injury in runners is diagnosed by acute inflammation of the tendon. Achilles tendinopathies are a result of chronic damage to the Achilles tendon. Much like Plantar Fasciitis, the cause of Achilles tendinopathies is still being researched. Some theories include the amount of tensile loading, shearing forces, hyperthermia, scarring, and tissue weakness. Risk factors for Achilles tendinopathies include age, gender (male are more prone to injury), training errors, shoe/foot characteristics, pronation, soft surfaces, and temperature. Because tendinopathies are considered an overuse injury, it is believed that they are a result of a combination of multiple factors (Lorimer, 2014).

Although, multiple risk factors may be present, some may have a larger effect on the Achilles tendon than others. Some studies have seen trends that males over age 35 may have increased risk of developing Achilles tendinopathies, although, conflicting evidence exists , arguing age and gender as trivial factors. Training factors such as the accumulation of miles, increasing pace, or extreme hill training may have a larger effect on the Achilles tendon. Once again, researchers are unable to agree upon the level of effect running greater distances has on the risk of developing an Achilles tendinopathy (Lorimer, 2014). There have been studies suggesting that increasing mileage can increase risk and studies arguing mileage only has a small effect on increasing the risk of an Achilles tendinopathy. Other evidence proposes that some individuals are able to withstand greater distances. Confounding factors such as the amount of resistance training and an individual's ability to stabilize may also influence the risk of developing and Achilles tendinopathy. It was also observed that individuals who trained at a faster pace than race pace, who ignored slower active recovery runs, were at increased risk of an Achilles injury, therefore, it is essential to address the importance of slower recovery paces to reduce the risk of injury (Lorimer, 2014).

Iliotibial band syndrome (ITBS)

Iliotibial band syndrome is the most common injury affecting the lateral side of the leg (Van der Worp et. al., 2012). It is a result of irritated structures around the knee from repetitive knee flexion and extension within an "impingement zone" at just below 30 degrees of knee flexion during the early stance phase. Within this zone, the tensor fascia latae and gluteus maximus eccentrically contracts to slow down the leg which results in tension in the iliotibial band (Van der Worp et. al., 2012). Because the tensor fascia latae is a major hip abductor which inserts on the iliotibial band, an individual who develops ITBS often times has weak hip abductors. It is generally suggested that a conservative treatment approach is a satisfactory recovery method for individuals suffering from ITBS. A conservative treatment plan can include "pain medications and injections, stretching the IT band and performing exercises that target the hip abductors and gluteal muscles" (Van der Worp et. al., 2012). Although these are common conservative treatments, seeking professional help, such as physical therapy, is recommended before attempting any personal rehabilitation.

Shoes

Much controversy exist surrounding running footwear and which type of footwear is ideal for an individual's technique and anatomical characteristics in order to maximize economy and reduce the risk of injury. In general, individuals with higher arches tend to experience more "heel pain, stress-fractures, and other structure-specific injuries" which may be caused by excessive loading rates and increased movement with "stiffer lower extremities" (Williams et. al., 2014). The eversion-to-tibial internal-rotation (EV:TIR) is a ratio that based on the structure of the arch and the position of the subtalar joint and relates the level of foot eversion to internal rotation of the tibia. When an individual makes initial contact with the ground, the foot everts, which is the primary motion of the foot that controls for shock absorption. At the same time the foot everts during initial contact, internal rotation of the tibia and pronation, or the inward rolling, of the foot is also observed. In high arched individuals it has been observed that there is decreased foot eversion and increased tibial internal rotation during the stance phase which may be associated with knee injuries. In one study, researchers found that runners with a rigid high arch illustrated a greater "initial loading rate, greater peak vertical ground reaction force, and decreased EV:TIR" than runners with a mobile high arch (Williams et. al., 2014). It has been suggested that runners with greater eversion, generally present in low-arched runners, may place additional strain on the foot and ankle; whereas, a runner with greater tibial-internal rotation in high-arched individuals may place strain on the knee due to the "transverse plane of motion of the tibia" (Williams et. al., 2014).

Pronation and supination are normal, healthy, movements of the subtalar and transverse tarsal joint during movement, however, excessive pronation can become problematic in runners. The first plane of motion during pronation is eversion, which is why often times pronation is referred to as eversion. Although this is considered the largest component of pronation, the subtalar joint also moves through abduction, or lateral rotation, in the transverse plane, followed by subtalar dorsiflexion in the sagittal plane. Similarly, the first plane of motion during supination is inversion, but subtalar adduction, or medial rotation, and plantarflexion of the foot is also observed (Muscolino, 2014).

Pronation allows the arches to drop and contour to the ground allowing for shock absorption, however, when the arches excessively drop it results in a pes planus, or flat feet. There are two types of flat feet which are determined by the reaction of the arches when weight-bearing. A rigid flat foot is always overpronated whether the individual is weight-bearing or not. Contrastingly, a supple flat foot is more common of the two, and occurs when the arches are healthy when non-weight bearing but collapse during weight-bearing activities (Muscolino, 2014). Although pronation may be one cause of flat feet, an individual's specific anatomy is important to consider as well. For example, an individual may have a normal level of pronation during the stance phase but may have increased joint laxity which causes the arches to drop, resulting in a flat foot. A simple weight bearing test can be done to examine an individual's anatomical characteristics. If the individual has a normal arch while non-weight bearing but once becoming weight-bearing, the arch collapses and the foot rolls inwards, the individual would more likely overpronate, whereas an individual who already has a flat foot or whose arch did not change with weight-bearing activity, would most likely not suffer from overpronation. Because the foot is the first body part to make contact with the ground, the kinetic chain can affect the level of pronation an individual exhibits therefore; proper pelvic and core stabilization can help to control the amount of weight-bearing pronation (G. Sewczak-Claude, March 29, 2016).

When it comes to choosing a shoe, individuals must understand the difference between supination and pronation and any tendencies they may have. Generally, an individual who overpronates is recommended a motion control shoe and an individual who under-pronates, a cushioned control shoe is recommended. An individual who has a normal amount of foot pronation is generally recommended a normal shoe (REI, 2016). While these are general recommendations, individual characteristics play a large role in determining proper footwear. For example, someone who naturally has a flat foot may not need a motion control shoe versus an individual with a flat supple arch who does need the support.

Additionally, when the arch lacks mobility it can cause an increase in compliance of the joints up the kinetic chain, especially the knee. Although high arched individuals typically have greater supination, or the outward rolling of the foot, and lesser pronation during the stance phase, mobile arched-individuals can have rear or mid-foot pronation due to compressive forces; therefore, an individual's kinematics can vary depending on the degree of arch (Williams et. al., 2014).

Depending on an individual's arch type, shoes have been designed to accommodate for certain tendencies common to each arch type. Generally, an individual with a low arch is recommended motion control shoes, whereas, an individual with high arches is recommended a cushioned shoe. A motion control shoe typically exhibits a stiffer midsole with a varus wedge and a cushioned shoe has a more compliant midsole. It has been observed that a motion control shoe decreases rear-foot movement, but may increase "lower extremity shock and ground reaction forces" in comparison to a cushioned shoe (Butler, 2006). On the other hand, a cushion shoe results in decreased tibial shock for both arch types. However, it is still generally recommended that because individuals with high arches are more prone to bony injuries, these individuals would better benefit from a cushioned shoe. Because low-arched individuals suffer more from overuse injuries associated with excessive rear-foot movement, a motion-control shoe is still usually recommended (Butler, 2006). It is important to have a good shoe fit no matter the arch index, as well as a gait analysis, to help individuals decrease the risk of injuries.

Recently, barefoot and minimalist shoes have become popular around the world. A barefoot running shoe is the minimal amount of coverage to protect the foot from objects on the ground with no heel or arch support. The toe-drop in a barefoot shoe is zero, meaning that the heel is not elevated in comparison to the toes. The idea of these shoes is to make running as natural as possible. A minimalist shoe has some heel cushioning, however, not as much as a motion or cushion control shoe, and provides limited heel stability. A minimalist shoe does have a small toe-drop ratio due to the increased amount of heel cushioning in comparison to a barefoot shoe (Davis, 2014).

Because research is limited on minimalist and barefoot running shoes, the benefits and limitations of these shoes remain undetermined, however, some studies have begun to see different injury associations and kinematics with these shoes. For example, individuals who run with barefoot or minimalist shoes tend to land on the mid or forefront of the foot. Researchers have noted that with minimalist running there is greater hallux dorsiflexion as the foot pushes of the ground. Some studies have seen that using a forefront or midstrike pattern during minimalist running reduces the amount of vertical impact forces and rates of loading (Davis, 2014).

When switching to a minimalist or barefoot running shoe, it is important to consider the changes in body mechanics and how those may influence injuries later on down the road. It has been seen that runners who transition too quickly are at higher risk for injury, such as metatarsal stress fractures (Davis, 2014) or "ankle overuse injuries like Achilles tendinopathies" (Perkins, 2014). One theory of this is that because a minimalist shoe usually causes a runner to run with a forefront pattern, it increases the eccentric work of the gastrocnemius and soleus which increases the load placed on the Achilles tendon. On the other hand there has been some evidence suggesting that minimalist running increases knee flexion during ground contact and decreases knee flexion during the stance phase, may reduce stress on the patellofemoral joint. In this case, minimalist running may be beneficial for individuals with knee problems, however limited evidence is present to support either finding (Perkins, 2014).

Transitioning into minimalist-type footwear can cause kinematic changes while running, and because the transition will most likely change an individual's running kinematics, the risk of injury increases. Conservative transition plans are generally recommended by starting out running shorter distances. This allows the muscles to increase strength and adapt to the new movement patterns. If muscles are not adequately conditioned, it increases the likelihood of muscle fatigue which can result in increased strain on the bones, therefore, along with a slow transition a strengthening program that includes foot and lower limb musculature is recommended (Davis, 2014).

Using the 10% rule of even increasing to 15% is an adequate guideline to follow during the transition. By only increasing mileage by 10%-15% each week, the muscles can adapt to the new biomechanics. Also, by partitioning the amount of running completed in the minimalist shoes and the traditional shoes, such as running half a mile in the minimalist shoes and a mile in the traditional shoes, it allows for movement pattern continuity. Because different biomechanics are required for walking and running, it may be most beneficial to continue running with both types of shoes as to maintain similar kinematics (G. Sewczak-Claude, March 29, 2016).

An individual who has a flat foot with previous instability and is transitioning from a stability shoe, may have greater difficulty transitioning into a minimalist shoe. This occurs because the stability shoe has been compensating for an individual's instability which over time decreases the functionality of the muscles causing the individual to be more unstable, resulting in the inability to properly stabilize the foot and ankle. This instability affects the entire kinetic chain, resulting in knee and hip instability. It may be beneficial to use a partial minimalist shoe as a gateway step when transitioning because it has some cushioning and support. Although a conservative plan is recommended, it is important to note that core and pelvic stability is required in order to maintain adequate biomechanics. The amount of stability in the hip, knee, and trunk of an individual is ultimately the determining factor for the level of shoe stability required (G. Sewczak-Claude, March 29, 2016).

Conclusion

Running is a versatile, life-long, activity that is seen throughout the world. Some individuals run as a profession, others run because of health reasons, and some even run because it is a way of life. Kenyan runners in particular are extremely adept at running and some theorize it is because running is an integral part of their life. Others theorize it is because of cultural ceremonies, training climate, and body shape. The Tarahumara people have given light to a new perspective on running which is character. They have shown the world their passion for running and the importance of the journey rather than the outcome of winning. In the United States, many people run because of the competition and enjoyment, but strikingly different than the Kenyans and the Tarahumara, many people also run for health reasons. Cardiovascular disease is the number one cause of death in the United States, and running can provide certain health benefits, such as reducing blood pressure, decreasing the risk for cardiovascular disease.

Form is an essential aspect when running in order to develop and maintain running economy as well as decrease risk of injuries. Although most of the active muscles are located in the lower body, working to propel the body forward, the upper body and the entirety of the kinetic chain is essential to maintain proper running form. Core stability plays an important role coordinating the kinetic chain, upholding postural stabilization, and allowing for a midfoot strike pattern.

Because running requires repetitive movements, there is an abundance of running related injuries. Plantar Fasciitis, Achilles tendinopathies, and Iliotibial Band Syndrome are common injuries that are thought to be caused by a number of different factors related to repetitive movements. Although there are a number of treatments available for these injuries, it is recommended to see a professional in order to determine the best treatment plan.

Running shoes have much controversy surrounding the optimal shoe type for an individual. Generally, an individual with a high arch who under-pronates is at higher risk for bony injuries so a cushioned shoe is recommended. On the other hand, an individual with a low-arch who over-pronates is at greater risk for soft-tissue injuries and is generally recommended a motion-control shoe. Barefoot and minimalist shoes are another shoe option that has become more popular since *Born to Run* came out, however, when transitioning from a traditional shoe to a minimalist shoe, a conservative, gradual conversion is suggested in order to allow biomechanical adaptations, decreasing the risk of injury.

The muscles contract allowing one foot to step in front of the other, the heart pounds as it pumps blood through the body, and the lungs expand as they fill with air, and the succinct coordination of these systems provide the individual the stamina and means to continue running. Many people have discovered that this experience has led to achieving optimal physical fitness, while also boosting personal well-being, leading to an increased interest in distance running. As distance running becomes more prevalent around the world, people should be aware of proper running technique in to reduce the risk of injuries as well as maximize personal goals.

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