THE IMPORTANCE OF FOOT-STRIKE PATTERNS IN RUNNING: A LITERATURE REVIEW

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Review paper

Abstract

Running has been defined as a product of integrated movement activities performed by different joints and body segments. Thus, an analysis of each joint and segment of motion, in addition to their relationships seems to be useful in order to assess the entire body movement trying aid to achieve a proper running technique. For this reason, understanding how the runner's foot makes contact with the ground during take-off and stance phases has special importance because the foot is the only body segment to directly supply force to the ground during the running movement. The aim of this review is to summarise the current literature on foot-strike patterns in running. Secondly, we discussthe influence of foot-strike patterns on various aspects related to running performance. In conclusio, the implementation of a "Running technique-specific training" seems to be crucial for improving performance in middle- and long- distance runners, as well Propriocetive and Plyometric training.

Keywords: *kinematics, running technique, performance, biomechanics*

Introduction

The Running is the object of many studies: theoretical and experimental, that joins biomechanics and motor control. Motor control and learning (Raiola, Tafuri, 2015, Guetano et al, 2015, Raiola 2014, Altavilla et al., 2014, Raiola et al 2014,) is the qualitative aspects of movement, although it is considered a little bit in quantitative aspects of locomotion, too. Also, the Situation Awarness (SA) (Di Tore, 2015) is consideredby the quantitative scientist way as a just theoretical paradigm without applicative aspects. Otherwise, the stretching play a role in muscle efficacy for the foot strike and running (Altavilla, 2014). This study on running focus on experimental way in a traditional vision of the scholarship. Middle- and long-distance running performances are closely related to physiological factors such as maximum oxygen consumption (VO2max), muscle fiber type, anaerobic threshold, and metabolic adaptations within the muscles(Noakes, 2001). However, biomechanical factors such as efficient running mechanics or the ability of the muscles and tendons to store and release elastic energy have recently been considered to be more important as contributing factors to achieving higher level performance in distance running (Saunders, Pyne, Telford & Hawley, 2004). Running has been defined as a product of integrated movement through different joints and body segments. For this reason, to carefully control each joint and segment of motion and their relationships with the entire body movement during running, may be useful for the assessment of a proper running technique. However, understanding how the athlete's foot makes contact with the ground during take-off and stance phases play a special role in running technique since the foot is the only body segment to directly supply force to the ground during the running movement (Hasegawa, Yamauchi & Kraemer, 2007). Typically, foot-strike patterns have been commonly considered for middle- and long-distance runners and their classification appears fairly clear: i.e. rearfoot-strike (RFS) where the heel contacts the ground first; midfoot-strike (MFS) where both the heel and ball of the foot land at approximately the same time; and forefoot-strike (FFS) where the ball of the foot contacts the ground first (Hasegawa et al., 2007; Cavanagh & Lafortune, 1980; Lieberman et al., 2010). Studies on long-distance runners of varying ability have reported that 75-99% RFS, 0-24% MFS, and the remaining 0-2% FFS (Hasegawa et al. 2007; Kerr, 2010, Larson et al. 2011). Middle- and long-distance RFS runners show greater ankle dorsiflexion to achieve initial heel contact; higher shock attenuation production and higher peak impacts (Delgado et al., 2013); longer contact time (Hayes & Caplan, 2012); and increased vertical GRF(Williams, McClay & Manal, 2000). In contrast, MFS and FFS runners show lower ankle dorsiflexion (Williams et al., 2000); higher average race speeds compared to FFS (Hayes & Caplan, 2012); and lower lumbar range of motion (Delgado et al., 2013). The aim of this paper is to summarise current literature on foot-strike patterns and their influence on various aspects related to running performance, providing methodological suggestions that can contribute to enhance performance in runners.In addition, we discuss the problems apropos to attempting a change in the natural foot-strike pattern, trying to suggest what is the best way to realize it.

Foot-Strike Patterns And Running Velocity

Hasegawa, Yamauchi, and Kraemer(Hasegawa et al., 2007) founded a trend towards reduced RFS and increased MFS in faster half-marathon runners. Middle-distance runners (800 m and 1500 m track races) are distributed as 27% RFS, 42% MFS and 31% FFS(Hayes & Caplan, 2012) but these results might clearly be justified by the type of shoes commonly used in this type of events and to increased running speed. Others researchers found that runners who predominantly RFS at running velocities below 18 km/h, shifted towards a more MFS or FFS at velocities above 18 - 21.6 km/h (Keller,Weisberger, Ray, Hasan, Schiavi & Spengler, 1996; Nigg, Bahslen, Luethi& Stokes, 1987). This was suggested to enable th em to cope with the higher collision forces associated with the higher velocities (Nigg et al., 1987). Recent research(Forrester & Townend, 2015) hasreported changes in foot-strike pattern related with velocity in recreational athletes' runners. The RFS - MFS - FFS percentages at running velocities below 18 km/h were consistently around 70 - 24 - 6%; thereafter, there was a substantial shift away from RFS towards MFS and FFS with the distribution being 47 - 47 - 6% at the highest velocity (Nigg et al., 1987). This supports an overall group trend away from RFS towards MFS and FFS at running velocities above 18 km/h. Other research has shown that habitually rearfoot striking runners are more economical than midfoot-strikers at 11 - 13 - 15 km/h(Ogueta-Alday, Rodriguez-Marroyo & Garcia-Lopez, 2014). Itcan easily be understood the evidence reported in this study being closely related to submaximal velocities, giving more credence to the idea that runner's foot-strike pattern is dependent on running velocity.

Foot-Strike Patterns and Performance

There is a considerable controversy about the influence of foot-strike pattern on running performance. Some studies have shown a lower percentage of rearfoot-strikers among elite performers than low performers (Hasegawa, et al., 2007;Kasmer, Xue-cheng, Roberts & Valadao, 2013), whereas others did not observe this trend(Larson et al., 2011). Both midfoot and forefoot patterns may enable a better stretching of the foot arch and a better storage and release of elastic energy from tendons, ligaments, and muscles of the lower limbs during the first part of ground contact (Lieberman et al. 2010;Perl et al., 2016). Midfoot and forefoot-strikers also have shown shorter contact time with the ground(Hasegawa, et al., 2007; Cavanagh & Lafortune, 1980;Ogueta-Aday et al., 2014), increasing leg stiffness and possibly improving running economy (RE)(Dumke, Pfaffenroth, McBride & McCauley, 2012). Unfortunately, a wide range of literature did not take into account runners' physiological characteristics or performance level, greatly reducing the quality of the assumptions made and any speculation about their findings. Just one interesting comparative study with high-level North African and European runners shows that lower ground contact time, smaller antero-posterior and vertical forces in the vertical component of the ground contact (typical of MFS and FFS)are associated with economical runners (Santos-Concejero et al., 2014;Williams, & Cavanagh, 1987). A recent study that compared simultaneously biomechanical and physiological parameters of runners, who naturally used different foot-strike patterns, showed no significant differences in RE between rearfoot and forefoot-strikers, although rearfoot pattern tended to be the more economical (Gruber, Umberger, Braun, & Hamill, 2013).However, this study, as well as that of Perl et al (2012) that analyzed the influence of foot-strike pattern on RE, were performed on recreational runners (each test was carried out at not more than 14.4 km/h) when, paradoxically, forefoot-strike pattern seems to be more common among high-level performers (Hasegawa, et al., 2007;Kasmer et al., 2013).Recent research has shown RFS and FFS runners did not differ in the amount of total lower limb mechanical work or average power when running at 16.2 km/h indicates that one technique does not offer a clearcut mechanical advantage over the other(Stearne, Alderson, Green, Donnelly, & Rubenson, 2014). This corroborates the other finding (Gruber et al., 2013) saying that no difference in metabolic cost exists between habitual RFS and FFS runners with the important addition that this study was performed at higher velocity. Saunders, & al. (Saunders, et al. 2004)have reported that forces experienced during ground contact of the gait cycle are the major determinants of metabolic demand, such as the cost of supporting the body's mass on his own feet and the time course generating this force that determines RE (Kram & Taylor, 1990). Thus, the great ground contact times and deceleration of horizontal speed during ground contact may be wasteful in terms of metabolic energy requirements (Nummela, Paavolainen, Sharwood, Lambert, Noakes & Rusko, 2006). Other studies have also observed a positive correlation of ground contact time and peak medial forces with submaximal VO_2, implying that the runners who have smaller antero-posterior forces in the vertical component during ground contact are more economical (Kyrolainen, Belli & Komi, 2001).It can easily be noticed how the parameters just mentioned can be associated with athletes who run at higher speeds and, therefore, high-level runners that demonstrate to strike with mid- or forefoot (Hasegawa, et al., 2007;Kerr, 1983, Larson et al., 2011). A new interesting parameter of the biomechanics of foot-strike directly related to RE in well-trained runners was presented in 2004 (Santos-Concejero et al., 2014).Practically, this study shows that stride-angle is significantly correlated with RE of runners who have run up to 15 km/h (Santos-Concejero et al., 2014).Stride angle is a measure that comprises stride length and the maximum height the foot reaches during swing phase, both features biomechanically driven by hip, knee, and ankle flexion-extension(Guex, Gojanovic & Millet, 2012). This phenomenon may be depicted in well-trained athletes as the ability of the foot to reach the glutes. This research suggested that stride angle may be an easily obtainable measure that reveals greater potential for running performance and RE than other biomechanical variables. Our speculation is based on the results observed by runners showing greater stride angles in concordance to a higher RE than their counterparts. It appears discordant with the results of other studies that has found that less economical runners exhibit greater total and net vertical impulse (Heise & Martin, 2001), which may imply steeper stride angles but who have analyzed just recreational runners running at lower velocities (12.06 km/h). In addition, it can be emphasised the greater stride angle could allow runners to take advantage to furtherbiomechanical variables during running. For example, stride angle may be a marker of the athlete’s ability to efficiently maximize swing time and minimize contact time with effective energy transfer during ground contact (Novacheck, 1998). This statement is supported by the strong correlations found between stride angle and ground contact time, implying that this feature of the swing phase may influence certain characteristics of the subsequent stance phase(Santos-Concejero et al., 2014a). This discussion is even more interesting when we notice that of the 25 athletes, 18 were forefoot-strikers (72%), 5 were mid-foot-strikers (20%), and 2 were heel-strikers (8%)(Santos-Concejero et al., 2014). Practically, we can suggest that greater stride angles might lead athletes to experience shorter contact times typical of mid- or forefoot-strikers, allowing a more economical running technique(Santos-Concejero et al., 2014;Nummela et al., 2006). This relationship may be related to the speed lost during the breaking phase (Nummela et al., 2006).Even more, this phenomenon has been speculated to be due to an early contraction of the muscles involved in the movement of a stride during the stance phase, leading the center of mass to be projected forward more efficiently(Saunders et al., 2004;Kyrolainen, Belli & Komi, 2001). Finally, other reasons that explain a better RE in MFS and FFS than RFS runners include a better stretching of the foot arch and release of elastic energy from the Achilles tendon, which may allow both midfoot and forefoot-strikers to save metabolic energy (Perl et al., 2012) and shorter ground contact times (Hasegawa, et al., 2007;Gruber et al., 2013), which have been related to increased leg stiffness and subsequent better RE(Dumke et al., 2012;Nummela et al., 2006). The prevalence of midfoot and forefoot-strikers among elite runners has been observed (Hasegawa, et al., 2007;Kasmer et al., 2013), which may indicate that a midfoot/forefoot-strike pattern is a desirable biomechanical feature. Another interesting speculation can be done about the study of Scholz, Bobbert, van Soest, Clark, & van Heerden (Scholz, Bobbert, van Soest, Clark, & van Heerden, 2008)concluding that for a given movement, the energy that is stored in a tendon is most sensitive to the moment arm of the tendon. The smaller the moment arm, the more energy is stored in the tendon at given kinematics and kinetics(Scholz et al. 2008). By definition, the moment arm of the Achilles tendon is the shortest distance from the line of action of the Achilles tendon to the center of rotation of the ankle (Scholz et al. 2008). Basically, a strong relationship was found between RE and the moment arm of the Achilles tendon. On consequence, a small moment arm is associated with high tendon energy storage. Any energy stored in the tendon does not have to be generated by the contractile element. Reducing contractile element energy generation is expected to lead to lower metabolic cost, because energy generation by contractile element is metabolically the most expensive process in muscle contraction (Scholz et al. 2008). The total metabolic energy consumption of a muscle, however, also depends on the amount of force that is generated (Minetti & Alexander, 1997), and muscle force is higher if the moment arm is smaller. Nevertheless, participants with small moment arms required less energy per kg body mass to run at the speed of 16 km/h(Scholz et al. 2008). Analysing what has been just stated, it is natural to wonder how the moment arm of the Achilles tendon can be releted with the foot-strike patterns during running. Seems to bebasical to suppose that a more neutral position of the foot before the strike typical of the MFS and RFS could lead to a smaller moment arm of the Achilles tendon. Subsequently, a more neutral strike could showa reduction of the range of motion of the joint just before the foot contact and during the early stance phase of gait cycle.The sequence of these events could allow a lower ankle dorsiflexion accompanied with a smaller moment arm of the Achilles tendon due to the fact that the moment arm can increase or decrease by muscle contraction (Ito, Akima, & Fukunaga, 2000;Maganaris, Baltzopoulos, & Sargeant, 1998)and it is a linear function of the ratio of changes in muscle force and tendon length(Kawakami, Nakai, Maganaris, Oda, Chino, Fukunaga, 2001). Thus, if MFS and FFS runners show lower ankle dorsiflexion (Williams et al., 2000), then they could allow to a more economical running technique and, therefore, improvement of performance. Even more, an higher ankle dorsiflexion produced during the RFS forces the Achilles tendon to move away from the malleolus causing an increase in moment arm contradicting, therefore, the theory according to which a small moment arm is associated with high tendon energy storage.However, these ideas are speculations arising from critical analysis of the various studies and empirical observations. Our conclusions are based upon the scientific literature reviewed in the present article, but additional studies would be required to further support our hypothesis.

Foot-Strike Patterns And Injury Risk / Prevention

Running has become an increasingly popular activity over the last decades and jointly the injury rate appears to increase in parallel, especially when running is practiced without specialists' direction. It has been shown that half of all runners will experience a musculoskeletal injury and subsequently will then be 50% more likely to become reinjured (Morley, Decker, Dierks, Blanke, French & Stergiou, 2010); therefore, researchaimed at preventing injuries and keeping these runners healthy is warranted. Research analysing running mechanics in an attempt to assess the origin of injury is warranted. Recent studies has examined barefoot and/or minimalist running in comparison to shod running (Lieberman et al. 2010;Divert, Baur, Mornieux, Mayer & Belli, 2005a;2005b, Giuliani, Masini, Alitz, & Owens, 2011). The purpose behind the barefoot/minimalist trend is to convert runners from a RFS pattern to a MFS or FFS pattern. Some author hypothesized that running barefoot implya decreasing risk of injury as this has been shown to produce lowerGround Reaction Forces(GRFs)(Lieberman et al. 2010). However, this is assuming that barefoot running will force runners into a MFS or FFS pattern. Also, barefoot running does not always induce this change and conversely can contribute to injury due to local pressures being in direct contact with the heel and no cushion to absorb the pressure (Divert et al., 2005b). Further research would be necessary to determine whether barefoot running has the potential to decrease injury in different populations as the resulting impact forces have produced mixed results (Lieberman et al. 2010; Giuliani et al., 2011, De Wit, De Clerq & Aerts, 2000). Recently several running experts have advocated that to strike the ground first with the heel is an ineffective technique. It was raccommended that landing on the midfoot or forefoot may better enhance the running efficiency and mechanics while reducing injury (Dreyer, 2003; B. Glover & S. F. Glover, 1999; Martin & Coe, 1991;Shorter, 2005). New investigations examining in more detail differences between the FFS and RFS showed conflicting results. For example, in some studies RFS has been shown to produce higher shock attenuation (Delgado et al., 2013) and longer ground contact time (Hayes & Caplan, 2012), while other studies have found higher peak impacts (Delgado et al., 2013)and increased vertical GRFs (Williams et al., 2000). Other divergences discovered include slower average race speeds for RFS compared to FFS(Hayes & Caplan, 2012), higher lumbar range of motion(Delgado et al., 2013) and decreased external dorsiflexion moments for FFS(Williams et al., 2000). The presence of an impact transient during RFS has been defined as a spike in the vertical GRF during the initial 50 ms of stance (Lieberman et al. 2010). It has been suggested that this impact transient only occur with a RFS running gait and it is also thought that there are important clinical implications for runners who have this spike during initial loading of the stance phase (Lieberman, & al., 2010). An interesting study, completed in 2012, presented results showing that habitually RFS runners have repetitive stress injuries at a rate 2.5 times higher than habitually MFS and FFS runners(A. I. Daoud, Geissler, Wang, Saretsky, Y. A. Daoud, Lieberman, 2012).The limitation of this study is that the 16 runners involved were all "Division I" college runners who self-selected a MFS or FFS pattern. While self-selecting a MFS or FFS pattern is fine and is often the sign of a high-level athlete, it's the conversion of a natural heel strike runner into a FFS strike runner that could result harmful. Certain kinematic and kinetic alterations can contribute to repetitive stress injuries. The ankle has been shown to play a significant role in the kinematic changes at the knee and hip during landing (De Wit et al., 2000). When runners perform a FFS pattern, the ankle comes into ground contact plantarflexed and typically landing occurs more directly under the center of mass (De Wit et al., 2000, Lieberman et al. 2010). The ankle position during the strike leads to decrease knee and hip flexion levels, thought an effort that minimize the vertical movement of the center of mass (Williams et al., 2000). One retrospective study has shown fewer injuries among habitually shod cross-country runners with an FFS versus an RFS (Daoud et al., 2012). However, to date, there are few prospective studies comparing injury rates between RFS and FFS runners.

Switching Foot-Strike Patterns: Possible Reasons And Implications

Even though 75 - 99% of runners naturally strike the ground with their heels (Hasegawa et al., 2007, Kerr, 1983; Larson et al., 2011), there is a growing trend among running experts to have lifelong heel strikers convert to a more forward contact point. The switch to a mid- and/or forefoot-strike pattern is supposed to reduce impact loads and enhance the storage and return of energy in our tendons (Lieberman et al. 2010, Perl et al., 2012)making us faster, more efficient and probably more immune to injuries. The reduction or lack of an impact peak (transient peak within the first 20% of stance) in the vertical GRF and lower vertical GRF loading rates during mid- or forefoot running may have implications for injury and pain reduction in runners with patellofemoral pain or anterior compartment syndrome when switching from an RFS to an FFS (Cheung & Davis, 2011;Diebal, Gregory, Alitz & Gerber, 2012). Further intervention study investigating injury prevention and rehabilitation should focus on the value of altering foot-strike patterns in athletes. Unfortunately, although appealing, the belief that switching to a mid- or forefoot contact point will alter injury rates and improve efficiency is not well known. Research evaluating injury rates associated with different contact points in more than 1600 runners has shown no difference in the incidence of running-related injuries between rear foot and forefoot-strikers (Kleindienst, Campe, Graf, Michel & Witte, 2007). Runners with heel versus mid/forefoot-strike patterns suffer a higher number of injuries due to the fact they absorb force in different areas. A simple investigation demonstrates that runners who strike the ground with their forefoot absorb more force at the ankle and less at the knee (Hamill, Gruber & Derrick, 2014). The opposite is true for rearfoot-strikers in that they have reduced muscular strain at the ankle with increased strain at the knee. This is consistent with several studies confirming that the choice of a heel or midfoot-strike pattern does not alter overall force present during the contact period, it just transfers the force to other joints and muscles: mid- and forefoot-strikers absorb the force in their arches and calves, while heel strikers absorb more force with their knees. Basically, choosing a specific contact point does not alter overall force, it just changes the location where the force is absorbed(Williams et al., 2000, Stearne et al., 2014; Hamill et al., 2014). In a detailed paper, it is suggested that competitive habitually RFS runners can successfully reduce their vertical and resultant impact GRF and loading rates when initially switching to a MFS or FFS, which may be beneficial for decreasing risk for running injuries(Boyer, Rooney & Derrick, 2014). However, it is possible that after habitually using an FFS the reduction may be attenuated (Boyer et al., 2014). This may put habitual mid- or forefoot-strikers at risk for impact-related injuries. Retrospectively, it was found that, in competitive runners who were habitually shod and who were habitually RFS runners, there was about twice the injury rate of habitually FFS runners. Although, this association was minimized and bordered on insignificance (possibly because of lack of statistical power) after removing runners who alternated between foot-strike styles (Daoud et al., 2012). Further studies are necessary to substantiate these findings. Pratically, in accordance with Boyer, Rooney, & Derrick (Boyer et al., 2014) shod rearfoot-strikers wishing to decrease their resultant or vertical loading rate may consider switching to an FFS because these variables decreased load in our study as well as others (Cheung & Davis, 2011;Diebal et al., 2012; Gregory, Alitz & Gerber, 2012, Kleindienst et al. 2007), and elevated vertical loading rate is associated with a history of stress fracture (Zadppor & Nikooyam, 2011). These decreases in loading rate, however, may be temporary (Boyer et al., 2014). Although an RFS is more predominant among long-distance runners versus an MFS and an FFS, the percentage of an MFS and an FFS has been found to be greater among elite distance runners (Hasegawa et al., 2007, Kerr, 1983) (although this may be related, in part, to increased running speed). The higher prevalence of an FFS in elite runners has contributed to a recent sub-culture among recreational and competitive runners to adopt an FFS pattern, despite the majority naturally preferring an RFS(Hasegawa et al., 2007;Kerr, 1983, Larson et al., 2011). In according to Stearne, & al. (Stearne et al., 2014) when habitual RFS runners were instructed to switch to an FFS technique, they were able to replicate the sagittal plane mechanics observed during habitual FFS running. However, despite there being no difference in ankle internal rotation moments or average moment rate between habitual RFS and habitual FFS runners, an imposed FFS increased these variables by 33% and 34%, respectively. Furthermore,when habitual RFS runners switched to an imposed FFS pattern, the total positive average power and the total negative average power increased by 17% and 9%, respectively. This increase in mechanical cost is possibly related to an increase in muscle work and power and thus may be detrimental to running performance. Thus, this study (Stearne et al., 2014) seems to strengthen the one conducted (Gruber et al., 2013)that found oxygen consumption increased when habitual RFS runners changed to an imposed FFS. The source of the increase in positive average power in imposed FFS running is primarily at the ankle and hip joints, whereas the increase in negative average power is primarily at the ankle joint(Stearne et al., 2014). A possible speculation is that the elastic mechanisms at the ankle are not as well developed in habitual RFS runners, and therefore, increased work at the hip joint is required to maintain the required work output. The prospect that the calf musculature in habitual RFS runners may limit their ability to effectively adopt an FFS technique was highlighted in a study (Williams et al., 2000)where RFS runners who performed a training session using an FFS experienced significant calf fatigue and delayed onset muscle soreness(Stearne et al., 2014). In summary, the results of the present research seems to be likely unclear and, therefore, further studies focusing on foot-strike Patterns in running should be carried out. It would be even more interesting to investigate these aspects among elite athletes, once is already known thatif the reasons that lead a rereational runner to a change of foot-strike pattern are related to an attempt to improve the performance, research evaluating metabolic cost of running also shows no clear advantage for a more forward contact point. In fact, some studies have suggested the vast majority of recreational runners are significantly more efficient with a RFS pattern(Ogueta-Alday et al., 2014).

Conclusions and practical application

When we consider the possibility of altering the foot-strike patterns, switching from the RFS to FFS pattern, firstly,it would be useful to carefully evaluate the ability of the athlete. Thus, the widelyissue is, since faster runners are mainly mid- or forefoot-strikers (Larson et al., 2011), while most recreational runners are more efficient with a heel-first strike pattern (Ogueta-Alday et al., 2014), at which levels of speed does a heel contact lose its relative metabolic advantage? A computer simulated study evaluating efficiency, researchers from the University of Massachusetts showed that while running at 13.2 km/h, heel striking was approximately 6% more efficient than MFS or FFS runners(Miller, Russell, Gruber, Hamill, 2009). Some recent research suggested that the 15 - 15.5 km/his the transition point at which there is no difference in economy between RFS and MFS/FFS patterns (Ogueta-Alday et al., 2014).These studies confirm that although highly skilled runners are efficient while landing on their mid- or forefeet and the majority of recreational runners are more efficient with a heel-first strike pattern. In summary, it would be useful to improve the athlete's economy without having focused on the attempt to change the way his feet strike the ground. Our opinion is that the work must pass through the "Running Technique Training"trying to teach to the athlete an appropriate manner to supporthisbody-weight on the feet (and more specifically on the forefoot) stimulating biomechanical and physiological alterations that lead the foot to strike on the ground in a more efficient way but with no obsessive focus on changing running foot-strike pattern. Furthermore, running technique exercises would bring improvements in the ability to apply force to the ground and consequently, improving the motionefficiency during running. When a coach or an expert athlete decides to alter his foot-strike pattern switching froman habitual RFS to an imposed FFS pattern, the total positive average power and the total negative average power increased and that this increase in mechanical cost is possibly related to an increase in muscle work and power jointly with the and oxygen consumption and thus may be detrimental to running performance (Gruber et al.,2013, Stearne et al., 2014). Considering the possible speculation according to which the elastic mechanisms at the ankle are not as well developed in habitual RFS runners, and therefore, increased work at the hip joint is required to maintain the required work output (Stearne et al., 2014) and the prospect that the calf musculature in habitual RFS runners may limit their ability to effectively adopt an FFS technique (Williams et al., 2000), it seems logical to see how specific training of mechanical components of the Achilles tendon could be decisive for the performance improvement. For these reasons, "Running Technique Training" should be integrated with regularity when there is the attempt to alter his foot-strike pattern switching from an habitual RFS to an imposed FFS pattern. In any case, the foot-strike alterations is recommended since FFS patterns may enable a better stretching of the foot arch and a better storage and release of elastic energy from tendons, ligaments, and muscles of the lower limbs during the first part of ground contact and lead to a performance improvement(Lieberman et al., 2010;Perl, Daoud, & Lieberman, 2012). Also, it seems to be advantageous to include "Proprioceptive Training" in combination with targeted exercises to stimulate the ankle joint. Proprioceptive training allows to: i) create instability *stimuli* at the level of the ankle and foot;ii) improve the ability to learn new skills,simultaneously with new types of training (Stillman, 2002); iii) bring improvements in nerve impulse conduction to the muscles used for support during running(Riemann & Lephart, 2002); iv) improve the way in which these forces are directed and distributed in addition to the production of higher amounts of strength, helping the control of foot movements(Riemann & Lephart, 2002); v) decrease the risk of injury (Riemann & Lephart, 2002). Another technique that provide decisive results (but applicable only after a correct progression of stimuli) is "plyometric training" associated with "explosive power training." Without forgetting that "Running Techninque Training" also includes plyometric and explosives movements, it could be crucial to include this type of stimuli to create stiffness improvements of the muscle-tendon compartment of ankle joint and increase the power generated.Therefore, it can beemphasised that increasing the power levels the athlete can generate may enable them to create higher power peaks in the shortest possible time. Furthermore, regardless of whether the athlete continues as a RFS or he switches to MFS/FFS, the result would likely not be restricted to just the biomechanical pattern, but also the contact time and, therefore, an improved GRF. Considering that athletes who are habitually MFS and FFS show shorter contact time with the ground (Hasegawa et al., 2007; Cavanagh et al., 1980;Ogueta-Alday et al., 2014) related with increasing leg stiffness and possibly improving running economy (Dumke et al., 2012;), it seems obvious that "Plyometric Training" is an important addition to the training regime. Definitely, if choosing to convert from an RFS to an FFS for long distance running (especially if also changing to minimalist footwear or barefoot), it should be done progressively and with caution to avoid injuries(Giuliani et al., 2011). The metatarsals may be more susceptible to injury when converting to an FFS (Giuliani et al., 2011) because the mid- or forefoot regions are loaded continuously throughout stance and experience greater shear forces at higher loading rate (Boyer et al., 2014). However, shod runners who are plagued by knee injuries anterior compartment syndrome may benefit by converting (Cheung & Davis, 2011;Diebal et al., 2012). Therefore, whether converting is appropriate may depend on which joint/segment is currently experiencing excessive loading.In addition, the converse train of thought should not be discounted. Bones, muscles and tendons need adequate stimulation to maintain and improve their integrity; as the magnitude of strain increases, the necessary loading frequency to induce osteogenesis decreases, and vice versa (Hsieh & Turner, 2001). Some running experts showed disagreement about the "Running Technique Training" and the method with which it is possibleto break the running stride into segments and do drills to improve that segment. Magness in his book affirms: "If you recall, each part of the running cycle impacts the next. The body works as a whole, not as a bunch of different segments. When drills are used, they may mimic visually what happens when running, but that is all. Due to doing drills in isolation, the muscle fiber recruitment pattern is much different. There is little contribution of the stretch reflex, the stretch shortening cycle, or elastic energy storage and return. Therefore, the drill has very little actual transfer to the actual running. For this reason, drills are not useful for improving mechanics because they do not replicate the running form biomechanically, neurally, or muscle recruitment wise. Instead running form should be worked on when actually running"(Magness, 2014). Therefore, to accomplish this, Magness (2014)found in "Cues" the solution to this problem. A cue is a simple task to focus on while running. Possible examples including putting the feet down, dropping the foot beneath you, extend the hip, or any other cue that helps reinforce proper running technique. What cues are used depends on what problem needs corrected. The athlete should focus on one or two possible cues at a time so that they do not get overwhelmed(Magness, 2014).

However, even if this theory seems to be logical, there is no scientific evidence that proves it. In summary, after a detailed analysis of the anthropometric, biomechanical and physiological characteristics of the athlete, although we agree with the general benefit of the "Cues" method,it is important to consider really decisive and effective its use in parallel with the implementation of the "Running Technique Training", "Proprioceptive Training" and, finally, "Plyometric Training" in any training schedule for middle- and long-distance runners, with the purpose to: i) improve the aspects related to the running performance; ii) reduce the injury risk; iii) create alteration of the foot-strike pattern and the running form.

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VAŽNOST UZORAKA AKCIJE NOGU O TLO U TRČANJU: PREGLED LITERATURE

Sažetak

Trčanje je definirano kao produkt aktivnosti integriranog kretanja izvođenog različitim zglobovima i segmentima tijela. Prema tome, analiza svakog zgloba i segmenta pokreta, u dodatku njihovoj povezanosti čini se korisnom u svrhu procjene kretanja cijelog tijela, nastojeći pomoći postizanju valjane tehnike trčanja. Iz ovog razloga razumijevanje kako stopalo trkača stvara kontakt s tlom tijekom polijetanja i fazi stava ima osobitu važnost zato što je stopalo jedini segment tijela koji izravno dostavlja silu tlu tijekom pokreta trčanja. Cilj ovog prikaza je sažeti trenutnu literaturu o uzorcima akcije nogu o tlo u trčanju. Drugo, raspravljamo o utjecaju uzoraka akcije nogu o tlo na razne aspekte povezane s izvedbom trčanja. U zaključku, implementacija ''treninga trčanja specifične tehnike'' čini se krucijalnom za napredak izvedbe u trkača na srednju udaljenost i trkača na veliku udaljenost, kao i propriocetivni i pliometrijski trening.

Ključne riječi: *kinematika, tehnika trčanja, izvedba, biomehanika*

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