Forefoot strike, rear foot strike or running shoes. Does it matter?

David Janoušek, Pavel Stejskal

Faculty of Sports Studies, Masaryk University, Brno

Abstract

The main aim of this article is to provide some insight into evidence-based data in running. The prevalence of a rearfoot strike (RFS) pattern is much more usual than a forefoot strike (FFS) even among elite distance runners. There has been significant pressure on runners to change their running style from RFS to FFS in recent times. Usually, this has been justified by the statement that FFS relates to a lower injury rate. Recent studies have shown however, that this statement is probably not true. Different types of strike pattern have an influence on loading different structures of the lower limbs, but the total incidence of running related injury is the same regardless of the type of foot strike pattern.

We want to provide not only an objective view on running technique but also an evidence-based view on the choice of running shoes. There are many recommendations to consider when choosing running shoes, especially in running stores, but only a few of them are supported by research.

This article is not a meta-analysis but it provides some evidence based information about running styles and running shoes.

Keywords: *forefoot strike, rearfoot strike, running, running shoes, foot strike pattern*

INTRODUCTION

There are a lot of recommendations about running technique these days, but not all of them are supported by evidence-based research. We can classify running technique according to the foot strike pattern into forefoot strike (FFS), midfoot strike (MFS) and rearfoot strike (RFS) (Lieberman, 2012). Forefoot strike is defined as a landing in which the ball of the foot hits the ground before the heel. Midfoot strike is a landing in which the point of the first contact of the foot with the ground is not only the rear third of the foot but the midfoot or entire part of the sole. Rearfoot strike is defined as a landing in which the heel hits the ground first and is followed by the ball of the foot (Cavanagh & Lafortune, 1980; Hasegawa, Yamauchi, & Kraemer, 2007; Lieberman, 2012).

It is possible to divide foot strike patterns according to the center of pressure at landing relative to maximum shoe length. This is called the foot strike index. If the foot strike index is less than 33% the pattern is a RFS, a MFS is between 34 and 66% and a FFS is 67% or higher (Cavanagh & Lafortune, 1980). However, Lieberman (2012) argues that this index is arbitrary concerning the foot's anatomy. He supposes to use the vertical ground reaction force (VGRF) instead of the foot strike index.

During running foot hits, the ground and causes an impact. It has been recognized that the RFS landings differ from FFS landings in impact peak in the VGRF and the shape of the curve of landing forces. The curve of RFS has two peaks however, the FFS curve has only one peak (Figure 1) (Lieberman, 2012).

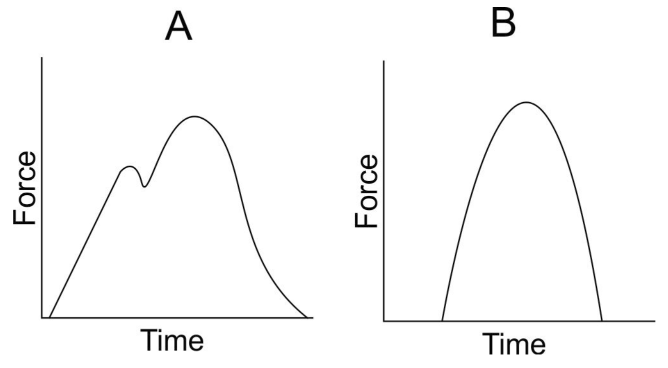

Fig. 1: Vertical ground reaction forces in the rearfoot strike (A) and the forefoot strike (B)

Many authors are using high-speed video analysis for the evaluation of the running pattern for its simplicity and effectivity (Hasegawa et al., 2007). For this reason, is the classification of the pattern based on the landing of the foot as was mentioned before.

The main aim of this article is to provide some insight into evidence-based data in running. We want to provide not only an objective view on running technique but also an evidence-based view on the choice of running shoes. There are many recommendations to consider when choosing running shoes, especially in running stores, but only a few of them are supported by research.

Pubmed, Scopus, Google Scholar, and Sport Discus were searched to identify articles for inclusion. Keywords were: *running, foot strike pattern, running technique, stride length, neutral shoes, running shoes, running economy.*

PREVALENCE OF FOOT STRIKE PATTERNS

The prevalence of foot strike patterns has been examined by many authors. Larson (2011) found that almost 90% of recreational and sub-elite runners at the 10-kilometer point of a half-marathon had a rearfoot strike pattern. De Almeida (2015) chose 514 recreational runners without injury and discovered that 95% of them had a rearfoot strike pattern. It looks like that most elite distance runners use the rearfoot strike pattern too. In the Osaka half-marathon at the 15km point, 74.9% of runners had a RFS, 23.7% used a MFS and 1.4% of runners had a FFS pattern (Hasegawa et al., 2007).

It can be argued that a RFS pattern is not natural, and is caused by wearing shoes. But foot strike pattern varies also among habitually barefoot runners in Kenya (Hatala, Dingwall, Wunderlich, & Richmond, 2013). In a group of 38 habitually barefoot runners running at their endurance speed, 72% used RFS and 24% used a MFS pattern. A FFS pattern was used very rarely, namely in 4% (Hatala et al., 2013). So, what can influence foot strike pattern? It turns out that one of the main parameters resulting in a change of foot strike pattern is running velocity. Kenya barefoot runners used RFS predominantly at velocities 5.0 m/s and less. At speeds between 5.01 and 6.0 m/s, the sample group used RFS and MFS with equal frequencies. At speeds between 6.01 to 7.0 m/s the majority used MFS. In the Hatala's group, the incidence of FFS was greatest at speeds between 6.01 and 7.0 m/s and FFS was never used by the majority of runners (Hatala et al., 2013). It seems that with higher speeds, elite long-distance runners adopt MFS and FFS more likely. This tendency is applicable to men and women runners as well (Hasegawa et al., 2007). Using only a FFS pattern is necessary for sprinters and middle-distance runners to obtain high running velocity (Ardigò, Lafortuna, Minetti, Mognoni, & Saibene, 1995). We can divide recreational road runners into three approximately equal sized groups according to their change of foot strike pattern (Forrester & Townend, 2015). The first group are runners who run using a RFS pattern regardless of the running velocity. They have lower stride frequency and a higher stride length. The second group are runners who use RFS at a slower speed and change their pattern to FFS with increasing running velocity. The third group are runners who use FFS regardless of their running velocity (Forrester & Townend, 2015).

INJURIES AND FOOT STRIKE PATTERN

A common myth is that forefoot strike pattern is associated with lower injury rates. There is plenty of literature which refutes this myth. Switching technique is associated with altered distribution in loading between joints. However, the amount of total lower limb mechanical work or average power when running are the same. It indicates that one technique does not offer a mechanical advantage over the other (Stearne, Alderson, Green, Donnelly, & Rubenson, 2014).

During RFS technique the hip and the knee are stressed more. During FFS the foot, ankle, and calf are stressed more. There is also a difference in muscle activation between FFS and RFS. FFS runners activate their plantar flexors 11% earlier and 10% longer than RFS runners. Earlier and longer activation of the muscles increase the capacity of the passive structures to store elastic energy. If the tendon is under tension before landing, then the force of landing would cause greater storage of elastic energy. This storage of elastic energy in the connective tissue of the tendon will increase the force output of plantarflexors at the end of the stance phase. On the other hand, this increases requirements on passive structures as Achilles tendon (Ahn, Brayton, Bhatia, & Martin, 2014). Very usual among runners are Achilles tendon injuries. Almonroeder (2013) established that FFS runners experienced 11% greater Achilles tendon impulse each step in comparison to RFS runners. It is not only the type of foot strike that influences the loading of joints. Increased stride frequency and reduced stride length both have the effect of decreasing load through the knee and hip (Lenhart, Thelen, Wille, Chumanov, & Heiderscheit, 2014; Schubert, Kempf, & Heiderscheit, 2014; Willson, Sharpee, Meardon, & Kernozek, 2014).

These data show that there is a clear difference between loading structures when comparing RFS and FFS. But running injury rates don't vary between RFS and FFS. Grier (2016) conducted a study in which there were 1332 soldiers. 83% of subjects were RFS runners and 17% were FFS runners. The authors found no difference in injury risk between FFS and RFS. However, they found a difference in most often injured segments of the lower limb. In RFS runners hip and knee were more likely injured than in FFS group, on the other hand in FFS runners the Achilles tendon and calf were more likely injured than in RFS group. But the total incidence of injuries was the same in both groups. Another paper was published by Warr (2014). In their study, they tested 341 male soldiers, and they did not find FFS to be advantageous for decreasing running related injury.

Runners who are suffering running relating injuries often should consider changing running attributes as a stride length and frequency. It is simpler to choose the only attribute of the running pattern than changing the whole technique. The deficiency in running technique will cause injury more likely in runner with higher loads due to the cumulative effect.

RUNNING ECONOMY AND FOOT STRIKE PATTERN

Running economy is the aerobic demand of running at submaximal pace. It means that there is a relationship between oxygen consumption and running speed. Running economy is influenced by many factors but most studies suggest that foot strike pattern alone is not a determinant of running economy (Nichols et al., 2016). Additionally, retraining from RFS to FFS does not change the running economy in recreational runners (Roper, Doerfler, Kravitz, Dufek, & Mermier, 2017). However, change from RFS to FFS can lead to reducing patellofemoral pain which is consistent with the findings that during RFS the knee is more loaded (Roper et al., 2017). However, there are some studies which conclude that a FFS pattern is more beneficial than RFS (Gillinov, Laux, Kuivila, Hass, & Joy, 2015), whereas, in contrast we can find studies that conclude that RFS is more economical than FFS (Gruber, Umberger, Braun, & Hamill, 2013). The results from studies investigating the effects of foot strike pattern on running economy vary, but as mentioned previously, most of the studies did not find a difference in running economy between RFS and FFS.

RUNNING SHOES

There are a wide variety of running shoes, for example motion control shoes, stability shoes, cushioned shoes or minimalistic shoes. Historically there has been a recommendation to prescribe shoes based on three basic types of foot. For flat feet or overpronating feet, a motion control shoe has typically been recommended. For normal foot, stability shoes were recommended and for high or supinated feet cushioned shoes have been recommended. The type of foot has usually been assessed by the wet footprint test during walking. However there is no association between these tests and dynamic function of the foot when running (Razeghi & Batt, 2002). According to the wet footprint test, foot pronation is a risk factor for injury. There are many studies to the contrary however (Beynnon, Renström, Alosa, Baumhauer, & Vacek, 2001; Neal et al., 2014; Nielsen et al., 2014). To the best of the author's knowledge, there are no set standards to determine the angle of pronation. Measuring pronation in the shoe has a lot of limitations, and markers on the shoe do not describe the position of the calcaneus within the shoe (Reinschmidt, Stacoff, & Stüssi, 1992). Cushioned shoes, sometimes called maximalist shoes are usually used for reducing impact loading during running. A recent study had the surprising result that high cushioned shoes increase impact loading during running (Kulmala, Kosonen, Nurminen, & Avela, 2018). Therefore, using this type of shoes for reducing impact seems to be in vain. Prescribing running shoes based on the shape of the foot has no significant effect on the incidence of running related injuries (Knapik et al., 2010).

If the wet footprint test is not reliable, how are we then able to appropriately choose running shoes? It seems that comfort is the key factor in choosing running shoes. Comfort in shoes is very individual and subjective but it can reduce the incidence of stress fractures and pain in different locations by 1.5–13.4% (Mündermann, Stefanyshyn, & Nigg, 2001). Crucial for runners is to regularly change their shoes and to rotate them regularly, which leads to a reduction in running injury risk by almost 40% (Malisoux et al., 2015). Participants in this study run, on average, approximately 19 km per week for single shoe users and approximately 33 km per week for multiple shoe users. Based on this data, it seems to be beneficial to change different types of shoes regularly, even among recreational runners who do not have very high volumes of training.

CONCLUSION

Changing foot strike technique for uninjured distance runners has no justifiable basis according to evidence-based data. If a runner suffers from running related injury often, changing attributes of the running technique such as stride frequency or stride length should be considered, rather than switching technique completely. Choosing running shoes should be led by comfort of the shoe rather than making a choice based on the type of foot. According to the research of Malisoux (2015) for distance runners whose training load is in excess of 25km per week, it is very beneficial to have more than two different pairs of shoes and to change them regularly. Changing different types of shoes leads to a significant reduction in running related injury risk. In youth athletes, it has been shown that athletes who participate in a variety of sports have fewer injuries and play sport longer than those who specialize before puberty. For adults, it is also beneficial to do more activities than only running because it decreases the risk of overuse injuries because of the use of different muscle groups.

Acknowledgements

The author acknowledged to Mr. Alex Floyd for his editorial comments.

References

Ahn, A. N., Brayton, C., Bhatia, T., & Martin, P. (2014). Muscle activity and kinematics of forefoot and rearfoot strike runners. *Journal of Sport and Health Science*, *3*(2), 102–112. https://doi.org/10.1016/j.jshs.2014.03.007.

Almonroeder, T., Willson, J. D., & Kernozek, T. W. (2013). The effect of foot strike pattern on achilles tendon load during running. *Annals of Biomedical Engineering*, *41*(8), 1758–1766. https://doi.org/10.1007/s10439-013-0819-1.

Ardigò, L. P., Lafortuna, C., Minetti, A. E., Mognoni, P., & Saibene, F. (1995). Metabolic and mechanical aspects of foot landing type, forefoot and rearfoot strike, in human running. *Acta Physiologica Scandinavica*, *155*(1), 17–22. https://doi.org/10.1111/j.1748-1716.1995.tb09943.x.

Beynnon, B. D., Renström, P. A., Alosa, D. M., Baumhauer, J. F., & Vacek, P. M. (2001). Ankle ligament injury risk factors: A prospective study of college athletes. *Journal of Orthopaedic Research: Official Publication of the Orthopaedic Research Society*, *19*(2), 213–220. https://doi.org/10.1016/S0736-0266(00)90004-4.

Cavanagh, P. R., & Lafortune, M. A. (1980). Ground reaction forces in distance running. *Journal of Biomechanics*, *13*(5), 397–406.

de Almeida, M. O., Saragiotto, B. T., Yamato, T. P., & Lopes, A. D. (2015). Is the rearfoot pattern the most frequently foot strike pattern among recreational shod distance runners? *Physical Therapy in Sport: Official Journal of the Association of Chartered Physiotherapists in Sports Medicine*, *16*(1), 29–33. https://doi.org/10.1016/j.ptsp.2014.02.005.

Forrester, S. E., & Townend, J. (2015). The effect of running velocity on footstrike angle--a curve-clustering approach. *Gait & Posture*, *41*(1), 26–32. https://doi.org/10.1016/j.gaitpost.2014.08.004.

Gillinov, S. M., Laux, S., Kuivila, T., Hass, D., & Joy, S. M. (2015). Effect of Minimalist Footwear on Running Efficiency: A Randomized Crossover Trial. *Sports Health*, *7*(3), 256–260. https://doi.org/10.1177/1941738115571093.

Grier, T., Canham-Chervak, M., Bushman, T., Anderson, M., North, W., & Jones, B. H. (2016). Minimalist Running Shoes and Injury Risk Among United States Army Soldiers. *The American Journal of Sports Medicine*, *44*(6), 1439–1446. https://doi.org/10.1177/0363546516630926.

Gruber, A. H., Umberger, B. R., Braun, B., & Hamill, J. (2013). Economy and rate of carbohydrate oxidation during running with rearfoot and forefoot strike patterns. *Journal of Applied Physiology*, *115*(2), 194–201. https://doi.org/10.1152/japplphysiol.01437.2012.

Hasegawa, H., Yamauchi, T., & Kraemer, W. J. (2007). Foot strike patterns of runners at the 15-km point during an elite-level half marathon. *The Journal of Strength & Conditioning Research*, *21*(3), 888.

Hatala, K. G., Dingwall, H. L., Wunderlich, R. E., & Richmond, B. G. (2013). Variation in foot strike patterns during running among habitually barefoot populations. *PloS One*, *8*(1), e52548. https://doi.org/10.1371/journal.pone.0052548.

Knapik, J. J., Trone, D. W., Swedler, D. I., Villasenor, A., Bullock, S. H., Schmied, E., … Jones, B. H. (2010). Injury reduction effectiveness of assigning running shoes based on plantar shape in Marine Corps basic training. *The American Journal of Sports Medicine*, *38*(9), 1759–1767. https://doi.org/10.1177/0363546510369548.

Kulmala, J.-P., Kosonen, J., Nurminen, J., & Avela, J. (2018). Running in highly cushioned shoes increases leg stiffness and amplifies impact loading. *Scientific Reports*, *8*(1), 17496. https://doi.org/10.1038/s41598-018-35980-6.

Larson, P., Higgins, E., Kaminski, J., Decker, T., Preble, J., Lyons, D., … Normile, A. (2011). Foot strike patterns of recreational and sub-elite runners in a long-distance road race. *Journal of Sports Sciences*, *29*(15), 1665–1673. https://doi.org/10.1080/02640414.2011.610347.

Lenhart, R. L., Thelen, D. G., Wille, C. M., Chumanov, E. S., & Heiderscheit, B. C. (2014). Increasing running step rate reduces patellofemoral joint forces. *Medicine and Science in Sports and Exercise*, *46*(3), 557–564. https://doi.org/10.1249/MSS.0b013e3182a78c3a.

Lieberman, D. E. (2012). What we can learn about running from barefoot running: An evolutionary medical perspective. *Exercise and Sport Sciences Reviews*, *40*(2), 63–72. https://doi.org/10.1097/JES.0b013e31824ab210.

Malisoux, L., Ramesh, J., Mann, R., Seil, R., Urhausen, A., & Theisen, D. (2015). Can parallel use of different running shoes decrease running-related injury risk? *Scandinavian Journal of Medicine & Science in Sports*, *25*(1), 110–115. https://doi.org/10.1111/sms.12154.

Mündermann, A., Stefanyshyn, D. J., & Nigg, B. M. (2001). Relationship between footwear comfort of shoe inserts and anthropometric and sensory factors. *Medicine and Science in Sports and Exercise*, *33*(11), 1939–1945.

Neal, B. S., Griffiths, I. B., Dowling, G. J., Murley, G. S., Munteanu, S. E., Franettovich Smith, M. M., … Barton, C. J. (2014). Foot posture as a risk factor for lower limb overuse injury: A systematic review and meta-analysis. *Journal of Foot and Ankle Research*, *7*(1), 55. https://doi.org/10.1186/s13047-014-0055-4

Nielsen, R. O., Buist, I., Parner, E. T., Nohr, E. A., Sørensen, H., Lind, M., & Rasmussen, S. (2014). Foot pronation is not associated with increased injury risk in novice runners wearing a neutral shoe: A 1-year prospective cohort study. *British Journal of Sports Medicine*, *48*(6), 440–447. https://doi.org/10.1136/bjsports-2013-092202.

Nichols, R., Germano, C., Burke, M., Nolan, K., Youngs-Grand, K., & Girard, J. (2016). The effects of foot strike on running economy in distance runners: A narrative review. *Physical Therapy Reviews*, *21*(1), 32–37. https://doi.org/10.1080/10833196.2016.1193970.

Razeghi, M., & Batt, M. E. (2002). Foot type classification: A critical review of current methods. *Gait & Posture*, *15*(3), 282–291.

Reinschmidt, C., Stacoff, A., & Stüssi, E. (1992). Heel movement within a court shoe. *Medicine and Science in Sports and Exercise*, *24*(12), 1390–1395.

Roper, J. L., Doerfler, D., Kravitz, L., Dufek, J. S., & Mermier, C. (2017). Gait Retraining From Rearfoot Strike to Forefoot Strike does not change Running Economy. *International Journal of Sports Medicine*, *38*(14), 1076–1082. https://doi.org/10.1055/s-0043-110225.

Schubert, A. G., Kempf, J., & Heiderscheit, B. C. (2014). Influence of stride frequency and length on running mechanics: A systematic review. *Sports Health*, *6*(3), 210–217. https://doi.org/10.1177/1941738113508544.

Stearne, S. M., Alderson, J. A., Green, B. A., Donnelly, C. J., & Rubenson, J. (2014). Joint kinetics in rearfoot versus forefoot running: Implications of switching technique. *Medicine and Science in Sports and Exercise*, *46*(8), 1578–1587. https://doi.org/10.1249/MSS.0000000000000254.

Warr, B., Fellin, R., Frykman, P., Sauer, S., Goss, D., & Seay, J. (2014). Footstrike Patterns do not Influence Running Related Overuse Injuries in U.S. Army Soldiers: 2977 Board #263 May 30, 3. *Medicine & Science in Sports & Exercise*, *46*, 812. https://doi.org/10.1249/01.mss.0000495935.37415.aa.

Willson, J. D., Sharpee, R., Meardon, S. A., & Kernozek, T. W. (2014). Effects of step length on patellofemoral joint stress in female runners with and without patellofemoral pain. *Clinical Biomechanics (Bristol, Avon)*, *29*(3), 243–247. https://doi.org/10.1016/j.clinbiomech.2013.12.016.