Original Article

Impact of various foot arches on dynamic balance and speed performance in collegiate short distance runners: A cross-sectional comparative study

Selvaraj Sudhakar^{a,*}, S. Veena Kirthika^a, K. Padmanabhan^a, G. Mohan Kumar^a,
C.V. Senthil Nathan^a, R. Gopika^a, Asir John Samuel^{b,*}

^a Faculty of physiotherapy, Dr. M. G. R. Educational and Research Institute University, Madhavoyal, Chennai, 600095, Tamil Nadu India

^b Department of Pediatric and Neonatal Physiotherapy, Maharishi Markandeshwar Institute of Physiotherapy and Rehabilitation, Maharishi Markandeshwar University, Mullana-133207, Ambala, Haryana, India

ARTICLE INFO

Keywords:

Exercise

Foot

Foot exercises

Foot muscles

Middle distance runners

ABSTRACT

Objective: To compare the impact of foot arches on dynamic balance and speed performance.

Materials and methods: 30 collegiate male short distance runners were divided into three groups based on foot arches, high, neutral and low. Balance and speed performance were estimated based on scores of star excursion balance test (SEBT), 40 yard dash test and vertical jump test (VJT).

Results: Significant improved scores ($p < 0.001$) were noted in SEBT, 40 yard dash test and VJT.

Conclusion: Short distance runners with high arch foot have improved dynamic balance and speed when compared to low and neutral arch foot.

1. Introduction

Newton's Law of Reaction says that, every action has an equal and opposite reaction. The force for the run is provided through the upward and forward ground reaction force in response to the downward, backward drive of the foot. Small vertical component of force has greater horizontal or driving component. In the most efficient run, vertical movements of the centre of gravity are reduced to a minimum. There should be no bounce in running.

In an efficient run, the foot should strike the ground as close as possible to the line of gravity. If the foot should strike ahead of the line of gravity, the reaction force to this forward and downward thrust will be a backward and upward force, acting to delay forward motion.¹ The more completely the horizontal force is directed straight backward, the greater its contribution to the forward motion of the body. Lateral motions are inefficient and detract from forward propulsion. But In Short Distance Running consist the series of ballistic strides in which the body is repeatedly launched forward as a projectile. These forces greatly absorbed by the arches of foot.²

The arches of the foot are maintained by a combination of bony structure, aponeuroses, ligaments and tendons.³ In some individuals these arches will not develop either in one foot or both. There is a strong relationship between the type of arch and injury risk. Moreover, it has been reported that individuals with flat feet feel fatigue in their feet more readily. In a strong foot, muscle activity is involved for

balance, adjusting the foot when encountering uneven surfaces, during locomotion. The foot posture can vary among healthy individuals, as well as runners.⁴ The foot is classified into three following category depending on arch height. They are pes planus (PP), normal, and pes cavus (PC) foot types. The PP also known as flat foot, here the excessive pronation, due to this ankle fail to stabilize the body, which decrease the ability to absorb shock properly but speed of running is not affected.⁵

In PC the arch is higher than normal and causes clawing of the toes. There are lateral variation and rotation of the hallux, together with hypertrophy of the medial part of metatarsal head and an overlying bursa which together form a prominent bunion on the medial side. Lateral variation of the hallux may lead to overcrowding and occasionally overriding of the lateral toes results in uneven distribution of force causes shock traveling up the legs.⁵

Since running is a linear motion of the entire body, dynamic balance, horizontal component of the momentum is much more important for speed performance than the vertical component. After preparing for ground contact, the emphasis is moved to a vertical pushing motion for maximal velocity sprinting.⁶ Although sprinting is a combination of pushing and pulling, the emphasis on vertical pushes will ensure that the athlete actively accelerates the thigh down towards the ground during the flight phase and will increase leg stiffness once ground contact time is made. This in turn will reduce ground contact time, recovery mechanics and increase stride frequency and length.^{4,7}

* Corresponding authors.

E-mail addresses: drsudhakar.acs@gmail.com, sudhakar.physio@drmgrdu.ac.in (S. Sudhakar), asirjohnsamuel@mmumullana.org (A.J. Samuel).

<https://doi.org/10.1016/j.jor.2018.01.050>

Received 13 August 2017; Accepted 14 January 2018

Available online 02 February 2018

0972-978X/ © 2018 Prof. PK Surendran Memorial Education Foundation. Published by Elsevier, a division of RELX India, Pvt. Ltd. All rights reserved.

Table 1
Demographic characteristics among short distance runners with various arches recruited.

Demographic characteristic	Group A (Low arch foot)	Group B (Neutral arch foot)	Group C (High arch foot)	P-value
Age (Years)	22.1 ± 3.9	22.9 ± 3.1	22.8 ± 3.3	0.8
Height (cm)	166.5 ± 3.7	168.1 ± 4.1	170.5 ± 8.1	0.7
Weight (kg)	64.5 ± 6.1	66.9 ± 7.2	67.5 ± 3.2	0.5
BMI (kg/m ²)	22.2 ± 2.8	21.9 ± 3.6	23.6 ± 1.5	0.9

Abbreviations: cm—centimeter; kg—kilogram; BMI—Body mass index.

However the relationship between types of foot arches and balance components among healthy sprinters has not at established and thus it becomes the need for present study.

2. Materials and methods

2.1. Recruitment and allocation

The study protocol was approved by the university research and ethics committee (ACS/2016/25) and the study was done strictly in accordance with the guidelines of Helsinki declaration, revised 2013. A total of 30 collegiate male short distance runners (CMSDR) were recruited by the simple random sampling (lottery method) to participate in this cross-sectional comparative study. They were recruited based on navicular drop test and talocalcaneal angle measurement which classified the foot under three category, pronated foot, normal foot and supinated foot. After the demographics, recruited subjects were divided into three groups based on their foot arches, group A (low arch foot/pronated foot), group B (neutral arch foot/normal foot) and group C (high arch foot/supinated foot). Signed informed consent was obtained from all the recruited collegiate short distance runners

The recruited subjects in comfortable dress performed vertical jump test, 40 yard dash test and star excursion balance test on consecutive days. Before beginning the session, the subjects followed standardized warm-up protocol for 8 min, which includes 5 min of static stretching (lower limb group muscle) and 3 min of jogging.

2.2. Measurement of vertical jump test (VJT)

In this procedure the subjects standing height was determined by

having the subject stand with the side of his dominant hand next to the wall, and heels together on the floor. With chalked finger-tips the subject reaches upward as high as possible and marks the wall. The subjects then assumes a position next to the wall with both feet on the floor. From this position the subject gather himself in a semi-squat position and jumps, making a chalk mark on the wall at the peak of the jump. Subjects were not allowed to hop, go off of one foot, or walk into the jump. The height jumped is measured distance between the standing reach height and the jumping height. Measurements were recorded in centimeters. Each subject received 3 trials jumps in succession, with approximately 15 to 30 s recovery between jumps and the best of the 3 jumps was used to calculate the subject score.^{8,9}

2.3. Measurement of 40 yard dash

40 yard dash test consists of a five yard running start to the starting line. The reason for a running start was to eliminate the skill factor of different subjects in starting performance. The subject began on whistle sound, five yards from the starting line and ended at 40 yard line consist of an end thread. Timing was measured manually using stopwatch which has operated in a 0.001 s mode. Each subject was given 3 trials of the 40 yard sprint, with rest recovery in between. The fastest of the three scores was used to report sprinting speed.^{10,11}

2.4. Measurement of star excursion balance test (SEBT)

SEBT is used to analysis the dynamic balance of the subject. The test was explained to each subject verbally, allowing the subject to ask any questions regarding the test. The test was performed with the subject maintaining a single-leg stance while reaching with the contra lateral leg i.e. the reach leg. The aim is to reach as far along the 8 directions as possible to touch the furthest point on the line as lightly as possible so as to avoid using the reach leg for support. The subject then returned to the centre of the grid on both feet whilst maintaining balance. Each subject performed 3 circuits of the SEBT. Each circuit consisted of 3 reaches (trials) in each of the 8 directions. Subjects were given a 5 s rest between each reach.^{12,13}

All the three sessions were performed in following order, VJP, 40 yard dash test and SEBT with 24-h rest between the sessions. They were compared and analysed.

Fig. 1. Mean star excursion balance test (SEBT) score among low arch, neutral arch and high arch foot in short distance runners.

Fig. 2. Mean 40 yard dash test score among low arch, neutral arch and high arch foot in short distance runners.

Fig. 3. Mean vertical jump test (VJT) score among low arch, neutral arch and high arch foot in short distance runners.

2.5. Data analysis

The collected demographic and outcome measures were assessed for their normality using Shapiro-Wilk test as the total sample size is less than 50 ($n < 50$). Normality analysis revealed that the data follow normal distribution, all the descriptive were expressed in mean $\pm$ standard deviation. ANOVA was adopted to find out the differences between Group- A, group-B and group-C. The data was analysed using statistical software, statistical package for social science (SPSS), IBM SPSS version 20.0 (Armonk, NY: IBM Corp.). The p -value ≤ 0.05 was considered to be statistically significant.

3. Results

Thirty short distance runners were recruited for the study. The demographic characteristic of CMSDR recruited were displayed in Table 1. There exists significance difference ($p < 0.001$) between the three foot arches of short distance runners. However, the short distance

runners with high arch have improved dynamic balance (Fig. 1) and speed performance (Figs. 2 and 3) when compared to short distance runners with low and neutral arches.

4. Discussion

The purpose of the current study was to explore the relationships between various foot arches, dynamic balance and speed performance in short distance runners. During running, most athletes first hit the ground with the outside border of the foot. Some with the rear lateral part of the foot (rear-foot strikers) and most others with the middle lateral region of the shoe (mid-foot strikers).¹⁴ Faster runners and elite sprinters spend much less time than 22% in the stance phase. Normally speed increases further and initial contact changes from being on the hind-foot to the forefoot. This typically marks the distinction between running and sprinting. Running is performed over longer distances and of these runners, approximately 80% are mostly referred to as rear-foot strikers. Most of the remainder is characterized as mid-foot strikers.

Sprinting is done over shorter distances at faster speeds. Short Distance Runners run with a forefoot initial contact and rarely make heel contact.^{3,8}

If comparisons are made between a foot type. A specific tendency can be identified, namely, a high arch foot and normal arch foot type has a faster forefoot contact than that of a low arch foot type. It is also clear that the high arch foot type, spends less time on the rear-foot than a low arch foot type with rarely any rear-foot contact.¹⁵ The results of this study also support the findings of research on foot types that being flatfooted decrease foot speed.

On comparing Mean values of Group A, Group B and Group C on Star Excursion Balance Test (SEBT), significant increase (Fig. 1) in the mean value was observed in high arch foot (84.7 ± 2.3 cm) and is more effective than normal arch foot (79.1 ± 6.4 cm) and low arch foot (72 ± 9.3). Similarly, in 40 Yard Dash shows (Fig. 2) significant increase in the mean value, but high arch foot demonstrated, 5.31 ± 0.4 s which has the lower mean value is more effective than normal arch foot (5.9 ± 0.7 s) and low arch foot (6.6 ± 0.5 s). Finally, on comparing mean values of Vertical Jump Test (VJT), high arch foot revealed (Fig. 3), 49 ± 4.4 cm which has the higher Mean value is more effective than normal arch foot (45.9 ± 2.5 cm) and low arch foot (41.9 ± 3.8 cm) at $P \leq 0.001$.

High arch foot type were more beneficial for short distance runners.^{3,4} These data suggested that athletes with a high arch foot type can be seen as possible candidates for speed performance such as sprinting and dynamic balance such as activities in general. This can be very important to athletes that low arch foot may lead to some overuse injuries which affects athletes speed performance and dynamic Balance. This study suggest that if foot arch problems are diagnosed earlier, it may decrease injuries in both athletic and sports activities.

5. Conclusion

There is a sufficient evidence form this pilot study to reveal that short distance runners with high arch foot have improved dynamic balance and speed when compared to low and neutral arch foot.

Conflict of interest

None of the authors have competing interest declared.

Funding

The Project was funded by first author (Selvaraj Sudhakar) and sixth author (R Gopika).

References

1. Kitaoka HB, Ahn TK, Luo ZP, An KN. Stability of the arch of the foot. *Foot Ankle Int*. 1997;18(10):644–648. <http://dx.doi.org/10.1177/107110079701801008>.
2. Thordarson DB, Schmotzer H, Chon J, Peters J. Dynamic support of the human longitudinal arch. A biomechanical evaluation. *Clin Orthop Relat Res*. 1995;316:165–172.
3. Chang Y-W, Hung W, Wu H-W, Chiu Y-C, Hsu H-C. Measurements of foot arch in standing, level walking, vertical jump and sprint start. *Int J Sport Exerc Sci*. 2010;2(2):31–38. <http://web.nchu.edu.tw/~biosimulation/journal/pdf/vol-2-no02/vol-2-no-2-b-0002.pdf>.
4. Morris JM. Biomechanics of the foot and ankle. *Clin Orthop Relat Res*. 1977;122:10–17.
5. Franco AH. Pes cavus and pes planus. Analyses and treatment. *Phys Ther*. 1987;67(5):688–694.
6. Lundberg A, Svensson OK, Bylund C, Goldie I, Selvik G. Kinematics of the ankle/foot complex-part 2: pronation and supination. *Foot Ankle*. 1989;9(5):248–253.
7. Manter JT. Distribution of compression forces in the joints of the human foot. *Anat Rec*. 1946;96(3):313–321.
8. Vadivelan K, Sudhakar S. To compare the effects of sprint and plyometric training program on anaerobic power and agility in collegiate male football players. *Int J Physiother*. 2015;2(3):535–543. <http://dx.doi.org/10.15621/ijphy/2015/v2i3/67027>.
9. Cordova ML, Armstrong CW. Reliability of ground reaction forces during a vertical jump: implications for functional strength assessment. *J Athl Train*. 1996;31(4):342–345.
10. Moore AN, Decker AJ, Baarts JN, et al. Effect of competitiveness on forty-yard dash performance in college men and women. *J strength Cond Res*. 2007;21(2):385–388. <http://dx.doi.org/10.1519/R-19495.1>.
11. Clark KP, Rieger RH, Bruno RF, Stearne DJ. The NFL combine 40-yard dash: how important is maximum velocity? *J strength Cond Res*. 2017(June)<http://dx.doi.org/10.1519/JSC.0000000000002081>.
12. Kinzey SJ, Armstrong CW. The reliability of the star-excursion test in assessing dynamic balance. *J Orthop Sports Phys Ther*. 1998;27(5):356–360. <http://dx.doi.org/10.2519/jospt.1998.27.5.356>.
13. Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star excursion balance test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther*. 2006;36(12):911–919. <http://dx.doi.org/10.2519/jospt.2006.2244>.
14. Hicks JH. The mechanics of the foot. *J Anat*. 1954;88(Pt 1):25–30. <http://dx.doi.org/10.1159/000141121>.
15. Scott SH, Winter DA. Talocrural and talocalcaneal joint kinematics and kinetics during the stance phase of walking. *J Biomech*. 1991;24(8):743–752.