

Correlation of foot posture with balance and pelvic tilt in healthy runners

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Abstract

Introduction. The purpose of the study was to find out the relationship of hyper-pronated foot with anterior pelvic tilt and dynamic balance in recreational runners. Hyper-pronated foot is a functional deformity which mainly affects the total body kinematic chain during dynamic weight-bearing events such as running when the foot lands on the ground. Furthermore, individuals with hyper-pronated foot may exhibit anterior pelvic tilt owing to the biomechanical relations, which alters balance as well. Runners with hyper-pronated feet are at high risk of injury, possibly because of larger torque generated at the lower limb.

Methods. A cross-sectional study was conducted in 55 healthy recreational runners with hyper-pronated foot aged 19–30 years. They were assessed by foot posture index for hyper-pronated foot, Star Excursion Balance Test for dynamic balance evaluation, and the photogrammetry method to determine the anterior pelvic tilt angle.

Results. The results revealed a poor correlation between foot posture index and dynamic body balance ($r = 0.23$) and a moderate correlation between foot posture index and anterior pelvic tilt angle ($r = 0.47$).

Conclusions. There was no significant correlation of foot posture index with dynamic body balance, whereas a minimal correlation was found between foot posture index and the anterior pelvic tilt angle. Therefore, hyper-pronated foot does not significantly directly influence balance or posture.

Key words: hyper-pronation, running injuries, dynamic balance, anterior pelvic tilt

Introduction

Foot pronation at the subtalar joint plays a crucial role in functional activities related to shock absorption and propulsion of the body during the dynamic phases of gait [1, 2]. Severe hyper-pronation of the foot is related to high risk of injury, probably because of larger lower extremity torques and increased internal tibial rotation [3, 4]. This has been considered as the most common cause of various lower limb injuries [5].

Running is one of the most popular physical activities enjoyed by people across the globe, and the numbers have grown up extensively over the past few years. The knee joint stands as the most frequent site of musculoskeletal injuries resulting from abnormal foot morphologies [6]. Evidence advocates that dynamic movement patterns of the lower limb can become influenced by some intrinsic foot pathologies [5]. It has been found that bilateral foot hyper-pronation can alter pelvic positions owing to the biomechanical connections like the posterior kinetic chain mechanism [7–9]. As far as balance is concerned, the ankle and hip strategies are interlinked to maintain the centre of gravity [10–12]. So even minimal biomechanical alterations at the support level can affect postural control strategies because of inappropriate afferent feedback [11].

It is evident that foot pronation can influence posture and balance, which in turn affect the total performance in running athletes [13–15]. A recent systematic review with a meta-analysis conducted by Hollander et al. [16] revealed evidence for an association between foot posture and subtalar joint kinematics and leg stiffness; no clear relationship was found for other biomechanical outcomes. Early evaluation of foot

posture and its influence can reduce musculoskeletal injuries and improve the athletic performance of runners.

There is, however, a dearth of literature to find evidence for the relationship of foot hyper-pronation with posture and dynamic balance. Some studies have mentioned the effect of foot hyper-pronation on lower limb biomechanics, posture, and balance in either healthy individuals or regular recreational runners [17–21]. Hence, the purpose of the study was to find the correlation of foot posture with dynamic balance and anterior pelvic tilt in runners with hyper-pronated foot.

Subjects and methods

Study design and participants

In this cross-sectional study, 55 healthy runners were recruited from various sports clubs of Mangalore and the outpatient department of Srinivas College, Mangalore, Karnataka, India. The participants were aged 19–30 years and represented both genders. They were included if they presented a foot posture index (FPI) score ≥ 7 in a clinical evaluation, had run at least 20 km weekly for 1 year, and had experience in a long-distance running competition [5, 22]. The runners were excluded if they had any history of low back pain, history of lower limb surgery or fractures in the previous year, neurologic diseases, concussion injuries within the previous 3 months. They were to exhibit a maximum limb length discrepancy of 1 cm and no neuromuscular problems or vestibular or balance diseases [13, 15]. An active knee extension test was performed, and subjects with angles exceeding 20° were excluded. A total of 130 runners were screened for

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eligibility; of these, 75 were excluded because of the following reasons: lower limb injury (38), FPI < 7 (16), no regular running practice (21).

A session was held at the dormitory to distribute consent forms and provide an overview of the research.

Measurements

The measurement session was conducted after the participants' routine warm-up program, which included 15–20 minutes of various drills (stretching, lunges, and jumping activities). In the first phase of the assessment, the foot posture was evaluated by using FPI. Then, dynamic balance was measured with a quantifiable clinical test called Star Excursion Balance Test (SEBT), and anterior pelvic tilt was determined with the photogrammetry method. All tests were performed by the fourth author to eliminate inter-rater reliability under the supervision of the first and second authors. To improve intra-rater reliability, all tests were taken 2 times (Spearman-Brown formula).

The foot posture was assessed for both feet, and the foot with the higher FPI score was examined as the reference leg. FPI was measured in the standing position, after which the examiner evaluated the subjects' 6 foot areas with either palpation or observation techniques. Afterward, the final score was calculated as the FPI composite score, as per previous studies [22]. Runners with FPI score ≥ 7 were included in this study [23]. The final composite FPI score was used for data analysis.

The subjects performed SEBT in 3 reach directions (anterior, posteromedial, and posterolateral). During the test, the runners maintained a unilateral stance position, and their anterior border of the 2nd toe was placed at the junction of 3 reach directions. The subjects were instructed to reach in all 3 directions with the free limb as far as they could while maintaining balance [24]. The distance reached in all 3 directions was measured in centimetres. All distances were normalized as a percentage of the stance limb length. Finally, the sum of the most significant reach distances for each of the 3 directions was divided by 100 to obtain the composite reach distance for each leg [25]. The composite score was used for data analysis.



Figure 1. Measurement of anterior pelvic tilt angle

The photogrammetry method was used to measure the anterior pelvic tilt angle. With the subjects in standing position, 2 reflective markers were put at the level of the anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS). As presented in Figure 1, 2 lines were indicated: between ASIS and PSIS, and a horizontal line through PSIS. The angle between those 2 lines was considered as the anterior pelvic tilt angle (Figure 1) and was used for further analysis [26].

Statistical analysis

The Kolmogorov-Smirnov test was applied to find out the normality of the sample for all the variables. Descriptive statistics served to establish the average values of all demographic and measurement variables, and as the data did not follow normal distribution, the values were expressed in median and range scores. Spearman's correlation test was used to determine the relationship of FPI with balance and pelvic tilt. A multiple linear regression analysis was conducted to verify if the FPI scores (independent variable) significantly affected the dynamic balance and anterior pelvic tilt angle (dependent variable). Statistical analysis was performed with the statistical software SPSS 20.0.0. (SPSS, Inc., Chicago, USA). Values of $p < 0.05$ were considered statistically significant.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Institutional Research Ethics Committee of Srinivas College of Physiotherapy and Research Centre. The study was registered under clinical trial registration No. CTRI/2019/10/021641.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Table 1 shows the descriptive characteristics of the participants. The nonparametric Spearman correlation test was used to find the correlations between the independent vari-

Table 1. Participants' descriptive characteristics

Variables	Values	
Subjects (n)	55	
Male/female, n (%)	45 (82%) / 10 (18%)	
Age (years)	22 (11)	
Height (m)	1.7 (3.8)	
Weight (kg)	61.5 (14)	
Body mass index (kg/m ²)	21.3 (6.2)	
FPI	Low hyper-pronation (FPI 7–9)	18 (33%)
	Moderate hyper-pronation (FPI 9–10)	20 (36%)
	Severe hyper-pronation (FPI > 10)	17 (31%)
Active knee extension (°)	15.4 (7)	

FPI – foot posture index

Table 2. Spearman correlations of foot posture index with Star Excursion Balance Test scores and anterior pelvic tilt angle

Sides	Variables	Spearman (r)	Coefficient (B)	p
Right	FPI-SEBT	0.232	0.018	> 0.05
	FPI-APA	0.473*	0.110	< 0.05
Left	FPI-SEBT	0.138	0.009	> 0.05
	FPI-APA	0.267*	0.060	< 0.05

FPI – foot posture index, SEBT – Star Excursion Balance Test, APA – anterior pelvic tilt angle

* statistically significant values

able of FPI and the dependent variables of SEBT and anterior pelvic tilt angle. Table 2 indicates that there was a poor correlation between FPI scores and the dynamic balance test ($r = 0.23, p > 0.05$) and a moderate correlation between FPI scores and anterior pelvic tilt angle ($r = 0.47, p < 0.05$). The FPI correlation with anterior pelvic tilt angle was statistically significant, but that with SEBT was not significant. The regression analysis also showed a poor association of FPI scores with dynamic balance ($B = 0.018$) and with anterior pelvic tilt angle ($B = 0.110$).

Discussion

Pronation is a complex multiplanar motion of the subtalar joint, which helps in increasing forefoot flexibility and shock absorption by locking the transverse tarsal joint during the gait cycle. The normal range of pronation is considered as 4–8°. Individuals with a higher degree of pronation are at a greater risk of developing overuse injuries of the lower limb, primarily owing to abnormal rotational moments and joint torques. This study was intended to investigate the relationship of hyper-pronated foot with anterior pelvic tilt and dynamic balance among recreational runners. The investigation revealed that hyper-pronated foot was poorly correlated with the runners' dynamic body balance and moderately correlated with anterior pelvic tilt angle.

Lubetzky and Kramer [17], on evaluating the association of various foot morphologies and dynamic balance, concluded that persons with decreased medial longitudinal arch height could reach farther in all directions except the anterolateral direction while performing SEBT, and there were no such balance deficits noted. Similarly, when measuring the effect of various foot postures on static and dynamic balance, Cote et al. [20] stated that there was no difference in static balance for pronated or supinated feet compared with control. So, it was hypothetically proven that the increase of dynamic balance with increased mechanical support of the medial aspect of a foot possibly resulted from improved sensory receptor activity and neuromuscular function [17, 20]. Similarly, a study exploring the influence of foot hyper-pronation and pelvis mechanics in standing position concluded that individuals with hyper-pronated foot presented greater anterior pelvic tilt angle compared with those with neutral foot position [18]. Another study on the relationship between foot posture and dynamic standing balance postulated a poor correlation between the variables [27].

The current study results are relatively comparable with the above evidence. The poor correlation of FPI with SEBT could result from functional adaptations. As far as balance is concerned, there could be some proximal kinematic compensation at the knee, hip, or trunk to maintain balance. Also, the type of shoes and the ankle and hip strategy might have played a significant role. In this study, the runners were evaluated for their dynamic balance in a static position, and only

healthy individuals were included, which might affect the results. On the other hand, while assessing the pelvic alignment, we found a significant association with FPI, possibly due to the anatomical and structural linkage. Additionally, hip strategy is among the proximal compensatory movements, apart from some abnormal truncal compensations like forward lurching to maintain balance by the resulting anterior pelvic tilt.

Though the hyper-pronated foot is moderately related to the body structures or anatomy, it cannot considerably influence the body mechanics or functions, and thus balance.

Limitations

The present study had a few limitations. First, the outcome measure, i.e. evaluating the foot posture and balance, was not the gold standard. Second, the runners were recruited from south India, so the results are hardly generalizable. Moreover, the hyper-pronation could have been categorized as low, moderate, and severe hyper-pronation and analysed further, providing some variation in the results.

Future recommendations

In accordance with the present study findings, runners can undergo foot posture assessment and pelvic alignment assessment as part of their pre-participation screening. Future studies are needed to determine the influence of compensatory kinematics at the hip, knee, and trunk with reference to dynamic events such as running and walking. Also, symptomatic individuals should be involved.

Conclusions

The current study results revealed a low correlation between the hyper-pronated foot and dynamic balance and a moderate correlation between the hyper-pronated foot and anterior pelvic tilt. The conclusion is that hyper-pronated foot or altered foot posture can only modify the anatomical or structural connections, but cannot be a strong factor altering balance or kinematics during dynamic tasks. Hyper-pronated foot alone cannot influence balance; there might be some compensations at the proximal kinetic chain for maintaining balance.

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Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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