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Effect of foot posture on plantar support during gait of adult beginners in running

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ABSTRACT

OBJECTIVE

Running is a sport activity that has been growing worldwide. However, most beginner runners are affected by injuries, with the foot type and plantar overload being the main risk factors for its appearance. The purpose of this study was to verify the effect of foot posture on the plantar load distribution of beginning runners.

METHODS

114 novice runners from sports clubs in the state of São Paulo, with a rearfoot running pattern, were evaluated. The type of foot posture was evaluated using the plantar arch index recorded by the podoscope. Thus, runners were divided into three groups: cavus feet (CF, n=47), normal feet (NF, n=34) and flat feet (FF, n=33). Plantar pressure distribution was assessed using the pressure platform (Loran®,Italy), considering the feet regions (forefoot, midfoot and medial and lateral rearfoot). The variables measured were: maximum force and peak pressure. Analysis of Variance, followed by Tukey's post-hoc was performed, considering differences $p<0.05$.

RESULTS

Runners with cavus feet (high plantar arch) had higher peak pressure in the forefoot area and lateral rearfoot, such as maximum force on lateral rearfoot, in relation to groups with normal and flat feet, but decreased in the midfoot area. In the medial rearfoot, there were no differences observed between the groups. However, runners with flat feet reduced peak pressure over the forefoot and rearfoot areas (medial and lateral), but increased over the midfoot, when compared to cavus and normal feet.

CONCLUSIONS

Beginner runners with cavus feet posture increase the plantar load over the forefoot and lateral reartfoot regions while flat feet increase over the midfoot. These findings help to understand the need for gait training to improve the plantar load distribution pattern.

DESCRIPTORS

Running. Posture. Plantar pressure. Foot. Gait.

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INTRODUCTION

Running is a common sporting activity that is currently growing in popularity worldwide[1]. Studies have revealed that, of all sports, running has been the favorite among children, young people, and adults[1-3], because it is a versatile and low-cost activity[4,5]. Its attraction is based on its benefits for body health (including physical, mental, emotional, and social health), making it a common way to prevent inactivity[2,6,7]. However, due to the repetitive nature of running, its health benefits do not prevent the risk of running-related musculoskeletal injuries, which can impede training practice in 87% of novice runners, with an average recurrence rate of 71 days [8,9].

Compared with elite runners, novice runners are more vulnerable to injuries[10], partially because they are less physically prepared for distance running[11]. According to the literature, a physically conditioned runner following a structured training protocol may still be at risk of injury if biomechanical risk factors are not addressed[8,11-13]. The injuries most common in running include patellofemoral pain syndrome, medial tibial stress syndrome[9,14] and plantar fasciitis[14,15], with a 27% occurrence rate of ankle–foot complex[16]. After injuries, changes are observed the biomechanics of the lower limbs and feet support parameters during gait and running[17].

Thus, the relationship between biomechanics and running-related injury (RRI) has been studied, often with a focus on foot type (i.e., plantar arch), rearfoot pronation angle[18-21], and overload rate on the rearfoot area[19,22]. An elevated plantar arch can cause greater tensile stress on the plantar fascia, resulting in an increased loading rate on the rearfoot or forefoot during running[19,23,24]. Other studies have shown that the combination of an elevated plantar arch and rearfoot pronation angle is a good predictor of increased rearfoot plantar overload in both injured and uninjured runners[19,25].

Another important point is that excessive rearfoot pronation can promote changes in the lower kinetic chain, which may lead to the internal rotation of the tibia and/or knee valgus and the development of anterior knee pain syndrome and stress tibial fractures [24,26,27]. Based on this scientific evidence, many studies have focused on controlling these risk factors for injury prevention in runners. Thus, it is extremely important to verify how the foot posture can influence the plantar load pattern of novice adult runners, that is, those who started running, to better prevent the appearance of injuries. Therefore, the purpose of this study was to verify the effect of foot posture on the plantar load distribution of beginning runners.

METHODS

Study Design and Participants

This study was observational. A total of 114 novice runners (with an average of 1.0 years of experience; 45.4±8.1 years, 69.6±14.0 kg, 1.7±0.1 m), participated in this study. The recruitment was conducted through sports clubs related to running in the state of Sao Paulo (SP), Brazil. The runners were divided into three groups: cavus feet (CF, n=47), normal feet (NF, n=34) and flat feet (FF, n=33). The experimental procedure was reviewed and approved by the Departmental Research Committee of the Department of Health Sciences, Santo Amaro University (number 2.108.486). All participants who met the study criteria and provided written consent underwent a baseline running biomechanics assessment.

The eligibility criteria of the runners were as follows: one year of running experience, a weekly running distance of 20 km, one year of experience in distance running, a rearfoot running pattern, a history of knee and/or feet injury history but no history of lower limb trauma or fractures in the last six months, a difference in member length < 1 cm, and no other musculoskeletal disorders, such as neuropathies, obesity, rheumatoid arthritis, or bone spurs. In addition, they could not have prostheses and/or orthoses in the lower limbs (i.e., they must maintain a good general health status), so as not to generate bias in the interpretation of pace evaluations.

Measurement of the Foot Posture

To assess the plantar arch, the runners were positioned barefoot on a podoscope (CarciH) with a distance of 7.5 cm between feet. Footprints were captured with a digital camera which was positioned in front of the podoscope ata distance of 24 cm and a height of 45 cm, following valid and reliable procedures described by Ribeiro et al., (2016)[19]. The distance of 7.5 cm between feet to scale the image in AutoCAD 2005H was taken as a reference and used for the measurements. With the AutoCAD® software, a vertical straight line (L) was drawn from the second metatarsal to the center of the calcaneus. Then, the (L) line was divided into three parts for the delimitation of the forefoot, midfoot and rearfoot areas. To measure the medial longitudinal arch index (AI), the middle-foot area was divided by the total foot area: AI = Midfoot [B] / Forefoot [A] + Midfoot [B] + Rearfoot [C] (Ribeiro et al. 2016). The AI scores that defined each category were as follows: normal (0.21 to 0.28), high (<0.21), and low (>0.28) (Figure 1).

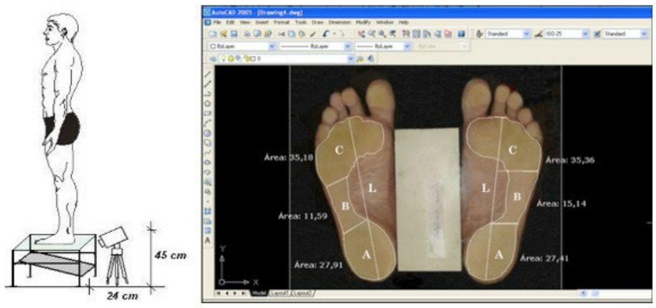

Figure 1: Positioning of the runner on the podoscope (A). Description of the calculation of the medial longitudinal arch index. L: vertical straight line, A: rearfoot area, B: midfoot area. C: forefoot area (B), adapted by Ribeiro et al., (2011)[18].

Measurement of the Plantar Pressure Distribution

The runners first walked on a pressure platform system (Loran®, Italy) placed halfway through a 10 m walkway. This instrument contained 99 resistive sensors, distributed homogeneously. Plantar pressure was recorded during barefoot walking at the preferred gait speed, and the data was acquired at 100 Hz. Gait speed was determined using a chronometer[28]. To minimize errors, two observers simultaneously recorded the start and end time of the gait, and interobserver reliability was performed, resulting Intraclass Correlation Coefficient (ICC) ICC=0.90. The system was calibrated before every evaluation using the participant's body mass.

The runners engaged in a period of adaptation of gait to the data collection environment for 5 mins. After adaptation, the runners walked on a flat track for a distance of 10 m, with the pressure platform located exactly at the midpoint. The steps that occurred in the 5 m in the center of the track were considered valid for analysis, totaling 12 steps per participant (right = 6 steps and left = 6 steps). Only the 5 m in the center of the track were analyzed in order to eliminate the acceleration and deceleration phases of gait. Plantar pressure was analyzed considering three plantar areas: rearfoot (30% of the foot length), midfoot (30% of the foot length), and forefoot and toes (40% of the foot length)[29]. The analyzed variables were the following: pressure peak (kPa) and maximum force (N).

Statistical Analysis

Calculations for the samples size of 114 runners was conducted based on the maximum force variable using the Bioinstat software (version 2015). A moderate effect size (F=0.25), an 80% power, and a 5% significance level were used in the calculation. An analysis of variance (ANOVA) was used to compare the effect of foot posture on plantar pressure variables, followed by Tukey's post-hoc, considering 5% significance level.

RESULTS

Initially, 117 runners volunteered for this study; 3 of them were excluded due to the preset criteria. The 114 runners completed all assessments and their anthropometric characteristics, such as the practice of running are shown in table 1 (Table 1).

Table 1. Anthropometric characteristics of novice runners evaluated.

Characteristics	Runners
Age (years)	45.4±8.1
Sex	58.3% (F); 41.6% (M)
Weight (kg)	69.6±14.0
Body Mass Index (kg/m^2)	24.4±4.2
Height (m)	1.7±0.1
Training Volume (km/week)	24.0 ±12.1
Running Experience (months)	18.5 ± 1.2

Runners with cavus feet (high plantar arch) showed increased peak pressure on the forefoot and lateral rearfoot ($p=0.047$ and $p<0.001$, respectively), when compared to groups with normal and flat feet. Another important observation was that the peak pressure reduced over the midfoot in runners with cavus feet ($p<0.001$). In the medial rearfoot, no significant differences were observed between the feet posture groups: CF, NF and FF, as shown in Table 2. In addition, runners with flat feet reduced peak pressure on the forefoot and rearfoot (medial and lateral), except in the midfoot area, which increased significantly ($p<0.001$) (Table 2).

Table 2. Mean, standard deviation and comparison between groups of foot postures: cavus feet (CF), normal feet (NF) and flat feet (FF) on the distribution of peak pressure during gait of the novice runners (beginner).

Peak pressure (KPa)	CF (n=47)	NF (n=34)	FF (n=33)	p
Forefoot	149.7±32.1	120.6±20.4	119.2±14.2	0.047*
Midfoot	74.6±31.8	108.0±27.5	120.7±32.4	0.001*
Medial Rearfoot	209.7±36.6	204.6±27.5	197.7±32.5	0.282
Lateral Rearfoot	198.5±33.8	190.0±26.3	179.4±30.2	0.041*

**ANOVA test, post hoc Tukey test, considering differences of p<0.05 significant.*

In the table 3 observed that novice runners with cavus feet showed an increase in the maximum force on the lateral rearfoot when compared to runners with normal and flat feet ($p=0.034$).

Table 3. Mean, standard deviation and comparison between groups of foot postures: cavus feet (CF), normal feet (NF) and flat feet (FF) on the distribution of maximum force during gait of the novice runners (beginner).

Maximum force (N / body weight)	CF (n=47)	NF (n=34)	FF (n=33)	p
Antepé	6.70±2.6	7.12±1.9	6.50±2.6	0.603
Mediopé	19.5±4.5	18.7±4.6	19.7±5.2	0.638
Retropé Medial	22.1±5.1	20.9±4.3	22.1±5.7	0.533
Retropé Lateral	12.5±9.1	11.1±8.6	9.7±8.9	0.034*

**ANOVA test, post hoc Tukey test, considering differences of p<0.05 significant.*

DISCUSSION

The objective of this study was to verify the effect of foot posture on the plantar load distribution of beginning runners (novice). In accordance with our hypotheses, the main results showed that the plantar support pattern of runners is influenced by the type of foot posture, in which runners with cavus feet increase the peak pressure on the forefoot and lateral rearfoot, as well as the maximum force on the lateral rearfoot; novice runners with flat feet increased peak pressure in the midfoot area when compared to runners with normal feet.

In the literature, In the literature, the association of the type of foot with rearfoot plantar overload during gait has been observed in non-athlete individuals, in which the authors observed a positive correlation between mechanical overload and the increase in plantar fascia thickness and pain symptoms. on the heel[30,31]. Other studies have shown an association of cavus feet and increased impulse force on the forefoot (integral of maximum pressure)[32,33]. The differential of this study was to demonstrate that novice runners, that is, beginners in the practice of running, who had cavus feet (high plantar arch) increased the plantar load on the forefoot and lateral rearfoot. This relationship could possibly result indirectly, in the tension and stretching of the plantar fascia of the feet, contributing to the development of injuries such as plantar fasciitis[19,25].

Another interesting observation found in this study was the increase in maximum force on the lateral rearfoot during gait in novice runners with cavus feet. Some studies, using a force platform, have observed an increase in plantar overload during running, especially in runners with cavus and flat feet[23,35]. In contrast, in this study, a pressure platform was used and assessments were made during walking and not during running, an activity that is more functional and routine. Other studies by Lees et al., (2005)[33] and Nakhaee et al., (2008)[34] did not observe a relationship between the plantar arch and the increase in force rates on the rearfoot runners.

The increase in peak pressure on the midfoot in runners with flat feet, may induce greater stretching force on the plantar fascia and greater demand for activation of the intrinsic musculature of the feet, for better stabilization of the ankle during running, as evidenced in studies with runners, with and without injury[26,36]. The clinical relevance of this study was to show that the clinical measure of the support of the rearfoot and forefoot is of fundamental importance for the health professional, as it allows to prevent the increase of the dynamic plantar load, in runners with cavus feet and increase of the plantar load in the midfoot in runners with flat feet, as already done by Ribeiro et al., (2015)[15] in injured runners, where it was observed that the characteristics of the types of feet and the alignment of the hindfoot, can predict the plantar loads of the runners, which can help the health professional, in choosing possible mechanical treatment strategies (orthosis, insoles and physiotherapy) to better control the proper distribution of the dynamic plantar load.

The limitation of this study was the impossibility of carrying out the kinematic analysis of the deformation of the plantar arch and the plantar load during gait. Future studies with this evaluation need to be carried out to better understand plantar support in corridors with different foot morphologies.

CONCLUSION

Beginner runners with cavus feet posture increase the plantar load over the forefoot and lateral reartfoot regions while flat foot increase over the midfoot. These findings help to understand the need for gait training to improve the plantar load distribution pattern.

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