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RELATIONSHIP BETWEEN FLAT FOOT AND VARIOUS GAIT PARAMETERS IN HEALTHY INDIVIDUALS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: The arch of the foot plays a vital role in transferring body weight and maintaining balance. Deformities in the foot arch may alter biomechanics and gait. This study aimed to determine the relationship between flat foot and gait parameters in healthy individuals.

Methods: A total of 112 individuals aged 18–30 years were screened for flat foot between May and December 2023. Plantar Arch Index (PAI) was calculated, and those with PAI > 0.26 (n = 35) were classified as having flat foot. Gait parameters—step length, stride length, step width, and foot angle—were measured using the footprint method. Data were analyzed using descriptive statistics and Spearman's correlation ($P < 0.05$).

Results: No significant correlation was found between bilateral flat foot and gait parameters. However, a significant positive relationship was observed between unilateral flat foot and step width ($r = 0.87$, $P = 0.024$).

Conclusion: Bilateral flat foot was not associated with altered gait parameters, whereas unilateral flat foot showed compensatory changes reflected in step width.

KEYWORDS: Plantar arch index, flat foot, footprint, gait parameters

INTRODUCTION

The foot can withstand high weight bearing loads and adapt to a range of surfaces and activities[1]. Foot is the only portion of the body that makes contact with the ground when performing weight-bearing exercises like standing, walking, hopping, and jumping It is vital to human movement. Any alterations to the foot's position could gradually worsen its functionality and increase the risk of injury when engaging in physical activity[2].

There are three arches in the foot: medial longitudinal arch, lateral longitudinal arch and Transverse arch[3]. The distribution of bodily weight is maintained proportionately by these arches. The arches of the feet play a major role in elevating the body weight, transferring internal pressures to the ground, and absorbing shock, all of which protect the body's internal structures from impact forces[4]. The longest and highest medial longitudinal arch (MLA), is crucial for shock absorption, mobility, and static support[5].

Flat foot (also called pronated foot) is a common foot deformity characterized by the disappearance of the medial longitudinal arch of the foot. Flatfoot can be the result of improper function of the medial longitudinal arch and subtalar joint, which damages the normal biomechanics of the foot[6].

The plantar fascia may be overstretched in the highly pronated foot, resulting in a rearfoot valgus posture. Overly flat feet can result in uneven load distribution across the entire foot complex. An overpronated foot can result in more excursions inside the foot and tibia, as well as subluxations in the foot joints. When walking, it may also have an adverse effect on the other lower extremity joints, such as the hip, internal rotation, flexion, and adduction, as well as valgus strain at the knee[7]. According to a 1991 gait analysis, adults who are obese walk slower, with a shorter stride length, and with a larger base of support than people who are not obese[8].

Excessive or prolonged tibial rotation and greater knee varus are frequently associated with an excessive or prolonged pronation of the foot. It is ineffective for finishing the push-off during a typical gait cycle[9].

Flat foot abnormalities can result in pain, instability, abnormal plantar pressure distribution, gait issues, and foot fatigue, all of which can significantly affect day-to-day activities. All of these adjustments may then result in a reduction in walking speed, an increase in stance time, a drop in stride length and cadence, and a decrease in overall well-being[10].

Though various studies have tested plantar arches and its role in ankle, very little evidence is available on finding the impact of flat foot and on balance and due to that on gait parameters Hence, in the present study is attempt made to find out the relationship between flat foot and gait parameters in healthy individuals. Understanding these relationships can help primary care physicians and physiotherapists identify early gait deviations related to arch collapse and prevent progression to overuse or postural disorders.

Null Hypothesis: There is no statistically significant relationship between flat foot and gait parameters in healthy individuals.
Alternative Hypothesis: There is a statistically significant relationship between flat foot and gait parameters in healthy individuals.

MATERIALS AND METHODS

This cross-sectional study was conducted among students at the College of Physiotherapy, Sumandeep Vidyapeeth. The study was conducted from May to December 2023 following ethical clearance (SVIEC No: SVIEC/ON/PHYs/BNMPT22/April/23/24. Written informed consent was obtained from all participants.
Inclusion criteria: Healthy individuals aged 18 to 30 years, having PAI >0.26 as flat foot and of both genders were included in the study.
Exclusion criteria: Individuals with a history of foot or leg surgery or trauma in the past year, swelling, ulcers, infections in the foot or ankle, or congenital foot deformities were excluded.
Convenient sampling was used. The present study did not include a formal sample size calculation as it was a time-bound study. However, all eligible participants who consented were screened for Plantar Arch Index (PAI) and those who had flat foot were included.

Study procedure

Total 112 subjects were screened and their PAI was assessed. 35 subjects had flat foot and hence selected for the study using following method.
To measure PAI: Participants dipped their feet in an ink pad and walked on white paper to produce footprints as shown in figure 1. PAI was calculated by dividing the area of the midfoot (B) by the total foot area (A + B + C), excluding toes. Classification: >0.26 was considered as flat foot [11,12].
Informed consent form was obtained from all the participants who had flat foot. Demographic data of gait parameters were then collected from all the participants.
To measure gait parameters: The footprint method was used to assess gait parameters of those 35 participants with flat foot (figure 2) such as step length, stride length, step width, and foot angle. Step length was defined as the distance between opposite heel strikes. Stride length was the distance between heel strikes of the same foot. Step width was the lateral distance between heel centers. Foot angle was measured between the foot axis and the line of progression [1].
Data confidentiality and participant rights were protected in accordance with the Declaration of Helsinki (2013).

STATISTICAL ANALYSIS

Data were analyzed using SPSS version 25. Descriptive statistics were calculated. Spearman's correlation was applied to examine relationships. A significance level of $p < 0.05$ was set.

RESULTS

A total of 112 participants were screened; 35 (31.3%) were classified as having flat foot. The mean age was 21.73 ± 2.1 years, and mean BMI was 22.79 ± 3.1 kg/m². Of the 35 participants with flat foot, 22 (62.8%) were females and 13 (37.1%) were males. No significant difference in PAI or gait parameters was observed between genders ($P > 0.05$).
There was no significant correlation between bilateral flat foot and gait parameters ($P > 0.05$). However, a significant positive correlation was found between unilateral flat foot and step width (Spearman's rho = 0.87, $P = 0.024$). Detailed correlation data are presented in Table 1 & 2.

DISCUSSION

This study examined the relationship between flat foot and gait parameters among healthy young adults. The findings showed that bilateral flat foot did not significantly affect step or stride length, foot angle, or step width. However, unilateral flat foot demonstrated a significant positive correlation with step width, suggesting compensatory gait adjustments to maintain balance.
The present sample was relatively small, and unequal gender representation could have influenced the findings. Prior studies have reported sex-related differences in arch height and gait mechanics, which may partially explain the variability observed.
Present study shows only 35 subjects out of 112 had flat foot. ,In the study done by Darshita Fatnani et al, out of 120 subjects, 41 (34.2%) had flat feet and 61 (50.8%) had high arch, and the remaining 18 (15%) had normal foot arches. This may be because flat foot resolves on its own after the first ten years of life[13]. Several studies have discovered that flat feet are more common than highly arched feet. According to the study done by Anjana J et al. arch of the people now days are more deviated because graduates in allied health are required by their profession to do clinical tasks in a hospital setting for extended periods of time while standing[14]. Pavan G et al (2021) found that there was no significant correlation between age or gender with flat foot[11]. Anjana J et al (2021) found that flatfoot was more common in females than in males[14].
In the current study, footprints method was used to measure plantar arch index and gait parameters. Chinmay Patel et al in their study justified that it is preferable to obtain the subject's footprint in order to analyse the arch-index rather than doing unnecessary, expensive radiological procedures The footprint method provided a practical, non-invasive means of assessing PAI and gait. Despite the small sample size, this study adds valuable insight into gait compensation mechanisms in flat-footed individuals[15].

The current study demonstrated no statistically significant correlation between bilateral flat foot and gait parameters. However, when analysing the relationship between unilateral flat foot and gait characteristics, a significant positive correlation was observed specifically with step width. This suggests that individuals with unilateral flat foot may exhibit compensatory changes in their gait to maintain balance, possibly due to asymmetrical foot mechanics.

Supporting literature indicates broader implications of foot arch abnormalities on gait and postural control. Eloho N et al. (2022) reported that the prevalence of flat feet tends to decrease with advancing age, suggesting a possible natural correction or adaptive response in foot structure over time[12]. J.F. Hornestam et al. (2021) found that bilateral increases in foot pronation can lead to subtle but meaningful changes in pelvic mobility. Their study highlighted that during the loading response phase of gait, induced bilateral pronation was associated with reduced pelvic range of motion (ROM) in the frontal plane and an increased contralateral pelvic drop[16]. These changes imply that foot alignment can influence proximal joint kinematics, possibly leading to biomechanical inefficiencies or increased strain on the musculoskeletal system.

Similarly, Galli M et al. (2012) observed that adults with flat-arched feet demonstrated altered lower limb kinematics, particularly increased pronation during walking[17]. Such compensatory mechanics may disrupt the natural rhythm of the gait cycle, potentially leading to changes in stride dynamics, pelvic alignment, and muscular activation patterns.

The findings of this study add to the limited evidence on how variations in foot arch structure influence gait mechanics in otherwise healthy adults. Although the associations observed were modest, the positive correlation between unilateral flat foot and step width indicates a compensatory mechanism aimed at improving stability. Gender distribution and body mass index, known to affect foot morphology and gait, were not analyzed in depth and may have contributed to the observed variability. Considering the ease and low cost of footprint-based assessment, incorporating such screening tools in primary care or community physiotherapy settings could help identify early biomechanical deviations before they lead to musculoskeletal dysfunction.

Future studies with larger, more balanced samples and subgroup analyses based on gender and BMI are recommended to clarify these associations and to explore preventive interventions applicable in primary care practice.

LIMITATIONS

The study included a relatively small number of participants with flat foot, which may limit the power to detect small to moderate correlations. Gender distribution was unequal, and subgroup analyses were not performed. Although BMI data were collected, analysis by BMI category was not undertaken; future research should explore its potential effect on gait and arch structure. The single-center setting and footprint-based method further limit generalizability.

CONCLUSION

Within the limitations of this exploratory, small-sample study, bilateral flat foot was not associated with significant alterations in spatiotemporal gait parameters. However, unilateral flat foot demonstrated a positive correlation with step width, suggesting a compensatory strategy to maintain balance during walking. Although gender distribution and body mass index were not analyzed in detail, these factors may influence foot posture and gait and warrant further investigation. Early recognition of such gait deviations in young adults through simple screening methods, such as footprint analysis, can assist primary care and rehabilitation professionals in identifying individuals at risk for biomechanical imbalance and future lower-limb dysfunction. Larger, multicenter studies with balanced gender representation and BMI-based subgroup analysis are recommended to validate these findings.

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TABLES AND FIGURES

fig 1: Measurement of Plantar Arch Index using footprint method.

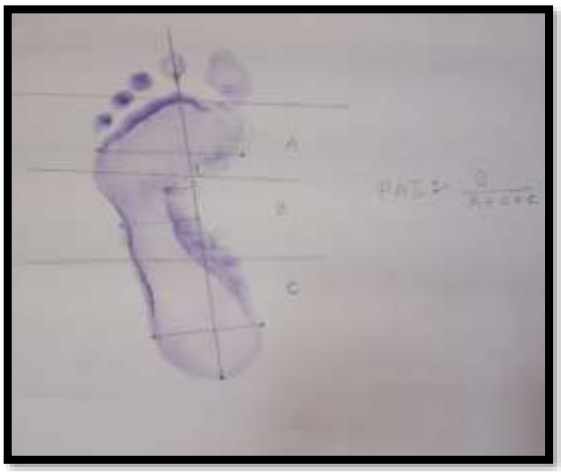

fig 2: Measurement of Gait Parameters using footprint method.

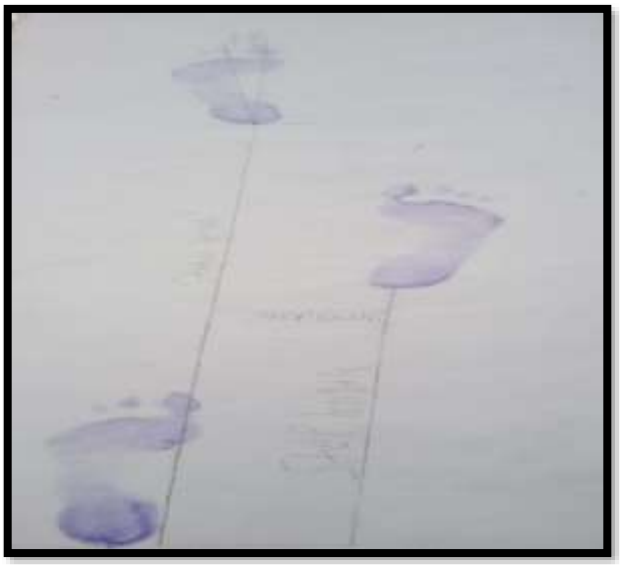

Table 1: Correlation between gait parameters and bilateral flatfoot

Test Variable (bilateral Flat Foot)		Spearman's R	P value
Step Length – flat foot	Right	-0.15	0.7
	Left	0.32	0.401
Stride Length – flat foot	Right	-0.19	0.624
	Left	0.28	0.465
Foot Angle – flat foot	Right	-0.22	0.569
	Left	-0.05	0.898
Step Width – flat foot	Right	-0.2	0.605
	Left	0.02	0.959

(Data expressed as Spearman's correlation coefficient; P < 0.05 considered significant)

Table 2: Correlation between gait parameters and unilateral flat foot

Test Variable (unilateral Flat Foot)		Spearman's R	P value
Step Length – flat foot	Right	-0.11	0.836
	Left	0.61	0.198
Stride Length – flat foot	Right	-0.18	0.739
	Left	0.52	0.290
Foot Angle – flat foot	Right	-0.15	0.777
	Left	0.61	0.198
Step Width – flat foot	Right	-0.38	0.457
	Left	0.87	0.024*

(Data expressed as Spearman's correlation coefficient; *P < 0.05 considered significant)