*International Journal of Health Sciences and Research*
*Vol.13; Issue: 11; November 2023*
*Website: www.ijhsr.org*
*ISSN: 2249-9571*
*Original Research Article*

# Correlation of Intrinsic Foot Muscle Strength with Forefoot and Hindfoot Posture in Patients with Flat Foot

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**DOI: https://doi.org/10.52403/ijhsr.20231127**

## ABSTRACT

**Introduction:** Foot is the main structure involved in locomotory activity. The anatomical segments of foot involve forefoot, midfoot and hindfoot. Pes planus is a common foot pathology constituting of collapse of the medial longitudinal arch, foot abduction at the talonavicular joint, and hindfoot valgus. Regardless of the type of flat foot, complications involve low back pain, knee pain, bunions, hammertoes, balance deficit, and increased chances of falls in elderly. Plantar intrinsic foot muscles are the small group of muscles responsible to maintain the medial longitudinal arch and various treatment protocols designed to manage pathologies related to flat foot.
**Method:** In this study total 130 patients with flat foot were selected and foot posture was obtained for forefoot and hindfoot with foot print analysis. The intrinsic foot muscle strength was measured with modified sphygmomanometer. Further values of both the foot postures were plotted on a graph with the values of intrinsic foot muscle strength to obtain a correlational relationship between the two.
**Results:** Intrinsic foot muscle strength showed a negative correlation with forefoot posture and no correlation was obtained with the hindfoot posture.
**Conclusions:** The intrinsic foot strength is negatively correlated with the forefoot posture in patients with flat foot i.e., with increasing amount of flat foot due to forefoot posture, the plantar intrinsic foot muscle strength declines, and no correlation of hindfoot posture with the strength suggests minimal contribution of hindfoot posture for strength deficit in flat foot.

***Keywords:*** pes planus, plantar intrinsic foot muscle [PIFM], Modified sphygmomanometer, Staheli arch index, Chippaux-Smirak index

## INTRODUCTION

The primary structure involved in all the human locomotion activities is the foot. Foot also is a part of the ankle and foot complex and has an important role in weight bearing [1][8] During weight bearing the ankle and foot complex must provide stability by providing a stable base of support by acting as a rigid lever for an effective push off phase during the gait cycle in order to avoid excessive muscular activity. The foot is not only involved in providing stability but also functions to serve the demands of mobility placed, by being flexible enough to act as a shock absorber to all the superimposed body weight placed on it, and thus conforming to a wide range of changing terrain.[1] The ankle and foot complex comprises of 28 bones that combine to form 25 component joints. The foot is segmentally divided into 3 parts. The forefoot (anterior segment) is formed by the metatarsals and phalanges, midfoot (middle segment) consists of navicular, cuboid and three cuneiform bones, hindfoot (posterior segment) of comprised of talus and calcaneus. The integrated movements of all these segments make the foot more functional.[1][8].

**INTRINSIC FOOT MUSCLES**

Intrinsic foot muscles are the small muscles of the foot rarely studied and evaluated functionally. These muscles work in conjunction with the extrinsic foot muscles, plantar ligaments and plantar aponeurosis and function to manage all the load demands placed on the foot during gait and contribute majorly to support the medial longitudinal arch.[1][4]. The plantar and dorsal intrinsic muscles of the foot both originate and insert within the foot. [[2][3][4]

**ROLE DURING REST:** plantar aponeurosis is a thick connective tissue supporting the plantar aspect of foot. Various EMG studies done previously revealed that the primary structure responsible for arch support during rest is the plantar aponeurosis and revealed that intrinsic foot muscles are not active during standing.

**ROLE DURING WALKING:** Reeser *et al.* suggested that intrinsic foot muscles act as trusses for the longitudinal arches, to actively resist deforming stresses during walking. This hypothesis can be supported by the findings that when the arch height is gradually increasing during late stance the plantar aponeurosis tension drops significantly .this lack of tension in the plantar aponeurosis suggests that other structures like the intrinsic foot muscles act primarily to provide arch support during the foot propulsion.[4][5], Furthermore a virtual study of the foot using the Finite Element Method has shown that mechanical stresses on the medial and lateral arch can be adjusted by plantar intrinsic muscles. [4] Therefore there is evidence that intrinsic muscles play an important role in the support of the medial longitudinal arch during gait and a small role in relaxed standing.[4]

**PLANTAR ARCHES.**

The foot comprises of three arches, the medial longitudinal arch, the lateral longitudinal arch and the transverse arch. The medial longitudinal arch being the largest and of maximum importance. [1]. The medial longitudinal arch which is formed the calcaneus, the talus and the three cuneiforms, and the first, second, and third metatarsals. Out of all the it is the most functional arch. Its summit is at the superior articular surface of the talus, and its two extremities or piers, on which it rests in standing, are the tuberosity on the plantar surface of the calcaneus posteriorly and the heads of the first, second, and third metatarsal bones anteriorly.[1][2] The arches of foot are the primary supports providing both stability and mobility during weight bearing activities. The provision of stability during weight bearing is done by uniform weight distribution throughout the foot and conversion of the flexible foot to a rigid lever. The provision of mobility during weight bearing is done by absorbing the weight during early stance phase and conform accordingly. The arch is hence flexible enough to dampen all the impact of weight bearing forces, conform to various changes in the supporting surface and also absorb and dampen the superimposed rotational forces placed over it.[1]

**PES PLANUS.**

Pes planus also known as flat foot refers to the loss of medial longitudinal arch which results to cause the medial arch of foot to come completely in contact with the ground or coming closer to the ground. [6]. The medial longitudinal arch of the foot is formed by a tough elastic connection of ligaments, fascia and tendons of the forefoot and hindfoot. It functions to disperse the weight bearing forces and also act as a compliant support base for the body. It also stores energy during gait cycle.[6][7]. Any biomechanical alterations in other joints of lower limbs are caused by dysfunctions in the arch complex and is usually asymptomatic. Hence this may also increase risk of pain and injuries.[6]. It is estimated that about 20% to 37% of the population has some degree of pes planus. A majority of these cases are flexible pes planus. Rigid pes planus is rare. It usually develops during childhood, but it can occur at any point in life. It develops from the tarsal coalition, accessory navicular bone, congenital vertical talus, or other forms of congenital hindfoot pathology.[6][7]

Present literature suggests of occurrence of biomechanical changes like forefoot inversion and rearfoot eversion in a flat foot. During gait cycle at heel strike, the calcaneus in low-arched individuals everts 32% faster than in people with high arches. The increased eversion velocity may be troublesome as it places greater strain on the restraining muscles and ligaments and the angular velocity of subtalar joint pronation may play a more important role in various injuries than the overall range of pronation.[19] Also, Intrinsic foot muscles are the important muscles responsible to maintain a normal foot arch and currently a very limited literature is available to address the intrinsic muscles strength variation with respect to the segmental anatomical foot posture with a proper consideration of forefoot and hindfoot and is rather based on the medial arch of the whole foot. Thus, a lot has been studied on a flat foot suggesting the kinematic motions of forefoot and hindfoot but there is very scarce literature to analyse if either of these components are related to the intrinsic foot muscle strength in a flat foot. Hence this study aims to analyse the correlation of the variation in intrinsic foot muscle strength with the flat foot with a special emphasis on forefoot and hindfoot foot posture.

## MATERIALS & METHODS

The study was conducted on a total 130 patients with flat foot. Study was approved by the ethical committee. Patients were selected according to the inclusion and exclusion criteria. The nature of study was explained and written consent was obtained from the patients prior to the study. Flat foot was classified according to the Outcome measure -navicular drop test. The forefoot posture was obtained with the outcome measure – Chippaux-Smirak index and the hindfoot posture was obtained with outcome measure Staheli arch index. The intrinsic foot muscle strength was assessed with modified sphygmomanometer. Then the forefoot and hindfoot posture were correlated with intrinsic foot muscle strength to obtain the results.

**Inclusion criteria:**

1. Age: 18-25
2. Both genders with flat foot
3. Patients with a value of >10 mm of navicular drop on navicular drop test.
4. Patients with value of>45.8% on Chippaux-Smirak index
5. Patients with value of >0.83% on Staheli arch index

**Exclusion criteria:**

1. Patients who underwent any foot surgeries
2. Patients with traumatic injury to the foot
3. Patients with foot deformities other than flat foot

**Materials:** Consent form**,** Record sheet, Ink paper, sphygmomanometer, scale, Pen

**NAVICULAR DROP TEST:** First, mark the navicular tuberosity. Next, measure the height of the navicular bone with the subtalar joint in neutral and the patient bearing most of the weight on the contralateral limb. Finally, have the patient assume equal weight on both feet and remeasure the height of the navicular. The difference between the first and second measurement is the navicular drop. A difference of >10 mm is considered significant excessive foot pronation

**FOOT PRINT ANALYSIS:** The foot print is obtained by taking the imprint of the foot coloured with ink on a paper. The foot prints will be then classified for forefoot and hindfoot postures according to Chippaux-Smirak index and Staheli arch index. The CSI is obtained by dividing the minimal distance of the midfoot by the maximal distance of the forefoot. The SI is the ratio of the minimal distance of the midfoot to the widest section of the rearfoot region.

**DOMING:** Doming is the action of foot which activates the intrinsic foot muscles. It is performed by activating muscles to pull the metatarsal heads towards the heel of the foot, effectively shortening the foot. Instructions for the doming action included, "keeping the toes on the ground, slide the ball of the foot back towards the heel," and "try to raise the arch without lifting or curling toes." Trials would be repeated if the patient by any chance lifts their toes, or the base of the metatarsals.

**MODIFIED SPHYGMOMANOMETER:** Modified sphygmomanometer is the tool used to assess muscle strength similar to a dynamometer. The inflated cuff is positioned and foot is placed over it and the desired muscle action i.e. doming is performed causing deflection in the mercury gauge depicting the strength of the intrinsic foot muscles. After the assessment and measurement of the foot posture and the intrinsic foot muscle strength, the values were correlated to obtain results for the same.

**DATA ANALYSIS AND RESULT**

The present study aimed at finding the correlation between the forefoot and hindfoot posture with intrinsic foot muscle strength.

The data collected was statistically analysed using Microsoft excel sheet and Instat Graphpad software. Total 130 patients, both male and female were selected according to the inclusion and exclusion criteria. The two parameters of forefoot and hindfoot were correlated with intrinsic foot muscle strength by calculating the spearman's correlation coefficient i.e. the (R) value was calculated. The data was then plotted with the help of a scatter graph to interpret the type of correlation observed. The various statistical measures such as mean, standard deviation (SD) and the test of significance (P) were utilised to analyse the data. 95% confidence interval was taken into consideration. The results were concluded to be statistically significant if, p value was <0.05.

A statistically significant correlation was observed between the forefoot posture and intrinsic foot muscle strength, whereas no correlation was to be found between the hindfoot posture and intrinsic foot muscle strength.

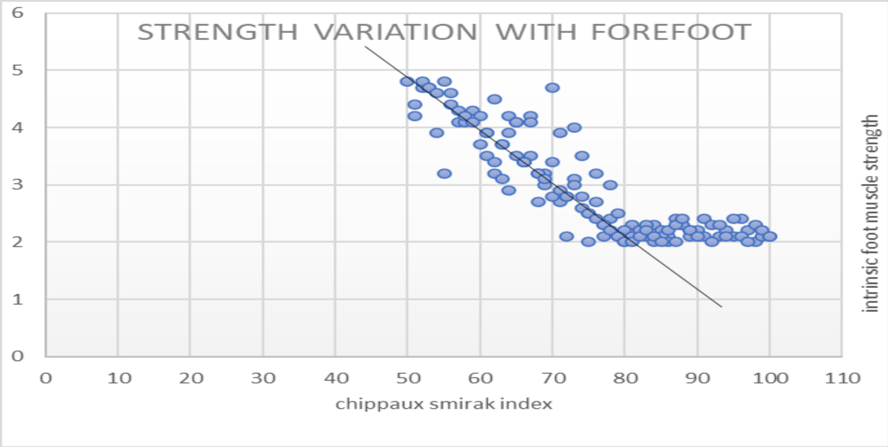
Hence the results show that the forefoot posture tends to affect the strength of intrinsic foot muscles more as compared to the hindfoot posture.

| MEAN ± SD of IFM strength | Correlational component | Correlational coefficient (R) | P value | Result |
|---|---|---|---|---|
| 2.891 ± 0.8767 | CSI with IFM | -0.9079 | <0.0001 | Extremely significant |
| | SAI with IFM | 0.0121 | <0.0001 | Extremely significant |

**1. Correlation between forefoot posture and intrinsic foot muscle strength**

This graph represents correlation between chippaux smirak index and intrinsic foot muscle strength.

**Graph no :01**

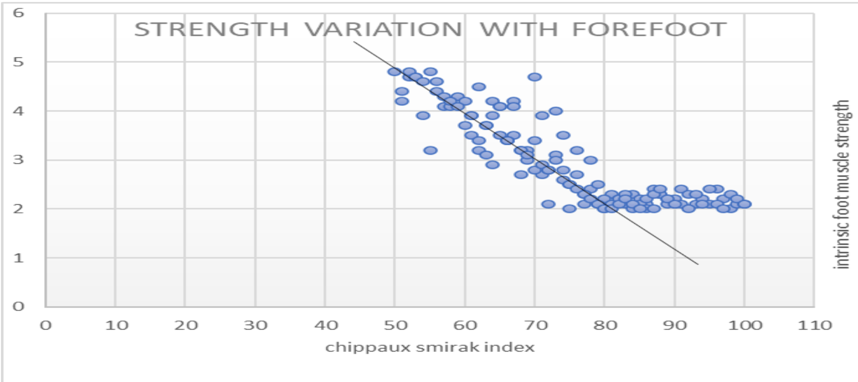



The correlational coefficient r = -0.9079, indicating a negative correlation of intrinsic foot muscle strength with forefoot posture.

**2.Correlation between hindfoot posture and intrinsic foot muscle strength.**

This graph represents correlation between staheli arch index and intrinsic foot muscle strength.

**GRAPH :02**




The correlational coefficient r = 0.0121 for intrinsic foot muscle strenght and hindfoot posture , is close to zero indicating no correlation of hindfoot and intrinsic foot muscle strength

## DISCUSSION

The present study aimed to establish a correlation between intrinsic foot muscle strength with the forefoot and hindfoot posture considering the two indexes i.e the and chippaux smirak index and staheli arch index respectively.

Thus, the purpose of the study aims at understanding the complex relationship between the segmental anatomical foot posture and the foot muscle strength and which component contributes more for the various anomalies related to foot pathologies.

Intrinsic foot muscle weakness could pose various issues causing reduced foot function. Also decreased torque production in the PIFMs may cause reduced generation of propulsive power and diminished dynamic balance, thus making it all the more important to quantitate changes in intrinsic foot muscle strength.

Pes planus with a fallen arch is found to cause increased motion and mobility of the forefoot which results in less stable base of support, which might be due to lack of sufficient torque production in the PIFMs. Thus, the intrinsic foot musculature is important in dynamic as well as static balance.

The mobility and stability are governed by the extrinsic and intrinsic foot muscles both. But the lack of literature evidences on the importance of mechanism of these muscles affecting the foot posture make this study relevant.

The anatomical changes occurring in flat foot include hindfoot eversion, talar inversion causing complete arch collapse allowing the talar head to make ground contact. Hence the talus is supported by the ground.[17]

Also, intrinsic foot muscles include various muscles but the key muscles involved includes the flexor hallucis longus which acts mainly at the forefoot compartment also supporting the results.[4][5]

A previous study done showed toe dynamometry as a method to quantify intrinsic foot muscle strength where the toe flexion occurring at MTP joint activates intrinsic muscles of foot which is also an action acting mainly on the forefoot, also supporting the results of this study explaining more correlation of anterior foot compartment i.e. forefoot with intrinsic muscle strength.

A statistically significant correlation was seen between intrinsic foot muscle strength and forefoot and no correlation with hindfoot. It was seen that the value of intrinsic foot muscle strength was decreasing significantly with the increasing amount of flatfoot considering the component of forefoot.

The reduced mobility occurring in the rearfoot as compared to the forefoot where the forefoot undergoes abduction with the talus and forefoot displacing anteriorly causing increased mobility at the forefoot which causes strain on the flexor digitorum brevis which counteracts this motion resulting decreased strength.[17]

The biomechanical changes occurring in hindfoot have not posed significant difference in the strength variations which can be explained by less mobility occurring in the hindfoot even in subjects with flatfoot.[17]

The results obtained of the ratio of hindfoot posture with midfoot statistically have found to overlap with various values of the ratio giving similar values of the SAI hence when correlated with varying values of intrinsic muscle strength have not given the perfect correlation.

Hence the correlation obtained with forefoot is consistent with the biomechanical changes and no correlation was obtained with the hindfoot considering the collapse of talus and the plantar arch.

## CONCLUSION

Hence this study concludes to establish a negative correlation of forefoot with intrinsic foot muscle strength.

And no correlation was found with the hindfoot posture and intrinsic foot muscle strength.

### Clinical Implications:

The study findings are of clinical importance since they indicate the forefoot posture affects the variation in intrinsic foot muscle strength in patients with flat foot more thus providing a base for understanding the specific segment of flat foot which affects the strength deficits causing foot pathologies. Thus, future studies considering the finding of this study could benefit to design treatment protocols to manage the condition.

### Limitations:

The elimination of activation of extrinsic foot muscles was not possible to be quantified.

### Future scope of study:

This study had a sole focus on the strength variation with the segmental anatomical posture and still a lot can be studied considering parameters like endurance of intrinsic foot muscles.

Also, further researches could be carried out assessing strength variation with gait parameters and so on.

Also, further studies could be done assessing the intrinsic foot muscle strength variations with the varying kinematics during gait, jump activities etc.

***Declaration by Authors***

**Ethical Approval:** Approved
**Acknowledgement:** None
**Source of Funding:** None
**Conflict of Interest:** The authors declare no conflict of interest.

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How to cite this article: Shruti Zungare, Abhijit Satralkar. Correlation of intrinsic foot muscle strength with forefoot and hindfoot posture in patients with flat foot. *Int J Health Sci Res.* 2023; 13(11):223-229.
DOI: *https://doi.org/10.52403/ijhsr.20231127*

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