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EFFECT OF STRENGTH TRAINING FOR INTRINSIC FLEXOR MUSCLE OF THE FOOT VERSUS BAREFOOT WEIGHT BEARING EXERCISE ON FOOT FUNCTION AND DYNAMIC PARAMETER AMONG INDIVIDUALS WITH FLAT FEET: AN EXPERIMENTAL STUDY

BHIMAVAT S[*1], VYAS D (PT)[*2] AND GADHAVI B (PT)[*3]

Parul Institute of Physiotherapy, Parul University, Waghodia, Vadodara, India

***Corresponding Author: Dr. Sakshi Bhimavat: E Mail: bhimavatsakshi@gmail.com**

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ABSTRACT

BACKGROUND:

Flat foot, also commonly described as pes planus, is a deformity of the foot marked by the collapse or absence of the medial longitudinal arch of the foot. The primary factors that are believed to give rise to an acquired flat foot deformity include dysfunction of the posterior tibial tendon, tightness of the triceps surae or isolated gastrocnemius, ligamentous laxity in plantar ligaments, and obesity. When the Medial longitudinal arch diminishes or disappears entirely, there will be a loss of balance and a reduction in shock absorption capability, which could lead to structural or functional deformation. Walking and running will become less stable as a result, which will decrease walking efficiency and endurance.

METHODOLOGY:

A total number of 150 individuals were selected in the study by using navicular drop test and Berkemann footprint. Out of which 120 were included. Based on inclusion and exclusion criteria, participants were recruited into two group. Group A consists of 53 participants and group B consists of 57. All the individuals were pre and post assessed for outcome measures for foot functions and disability on the basis of FADI and Dynamic parameter using one legged long jumping and vertical jump test before starting the intervention. Group A received Strength training for intrinsic flexor muscles of foot for 5 times a week for 4 weeks. Group B received Barefoot weight bearing exercise combined with strength training for intrinsic flexor muscles of the foot. The training period were for 5 times a week for 4 weeks. Subjects within the age group of 18-25years.

RESULT:

Statistical analysis was done using SPSS 25 (IBM). The result shows difference present between pre and post treatment when assessed with FADI, VJT and OLLJ test. The difference being significant with $p < 0.05$ suggest that there is improvement after the treatment.

CONCLUSION:

Present study concluded that there was significant improvement in both the groups for foot function and dynamic parameters that is FADI and VJT, but for OLLJ both groups were compared, Group A was found to be more effective than Group B.

Keywords: Strength training for intrinsic flexor muscle of the foot, Barefoot weight bearing exercise, Flatfoot, Short foot exercise, Foot and ankle disability index, Vertical jump test, One legged long jumping

1. INTRODUCTION

The human foot is composed of 28 bones and 33 joints (five main joint complexes: the ankle, the subtalar joint, the tarsal transverse joint, the tarso-metatarsal joint, and the metatarsophalangeal joint). The foot into four regions: the hindfoot (talus and calcaneus), the midfoot (cuboid, navicular, and the three cuneiform bones), the metatarsus (from M1 to M5), and the toes (from hallux to quintus). The foot has three extrinsic muscle regions located on the tibia and fibula: the anterior region (with the tibial anterior, the hallux long extensor, and the toes' long extensor muscles), the lateral region (with the long fibula and the short fibula muscles), and the posterior region (with the tibial posterior, the hallux long flexor, the toe long flexor muscles, and the sural triceps). Four muscle regions are intrinsic: the dorsal region (with the short extensor muscles of the hallux and of the toes), the medial region (with the abductor and adductor of the hallux, and the short flexor of the hallux), the lateral region (with the abductor of the quintus, the short flexor of the quintus, and the opposing muscle of the quintus), and the middle plantar region (with the short flexor of the toes, the plantar square, the interosseous dorsal muscles, the interosseous plantar muscles, and the lumbrical muscles) **[1]**.

The normal medial longitudinal arch is 15 to 18 mm from the ground at the level of the navicular, which is the keystone of the arch, whereas the lower lateral longitudinal arch is normally 3 to 5 mm from the ground at the level of the cuboid **[2, 3]**.

Flat foot, also commonly described as pes planus, is a deformity of the foot marked by the collapse or absence of the medial longitudinal arch of the foot. Flat foot and is classified into two general types; flexible flat foot and rigid flat foot. In flexible flat foot, the arch is present during non-weight bearing but disappears during weight bearing, while rigid flat foot is when the arch

is absent during both weight bearing and non-weight bearing **[4-6]**. The deformation into flatfoot is induced when the medial longitudinal arch (MLA) has descended because the arch had been excessively relaxed to the extent that the arch cannot be maintained and causes the feet to be excessively pronated compared to normal feet so that heel eversion appears and the weight load is shifted inward to compress the MLA **[7-11]**. Total prevalence of normal foot and pes planus in age wise distribution among adults. The highest prevalence and pattern of age wise distribution of pes planus observed in 20 years (24%), 18 years (16%), 19 & 21years (14%), 23 years (13%), and followed by 22, 24 & 25 years (10%,6%,3%). The highest prevalence of pes planus was observed in 20 years **[12-15]**.

Short Foot Exercise

Short foot exercises (SFE) are sensory-motor training that activates the intrinsic muscles of the foot and actively forms the longitudinal arch and the horizontal arch **[15-17]**. SFE contracted the intrinsic muscles of the foot to increase the inner arch of the foot, thereby shortening the longitudinal arch of the foot **[18, 19]**.

Barefoot Weight Bearing Exercise

Walking barefoot works by reinforcing the essential footstep in the body, there is less chance of impact and joint torque than in a shoe, and it also reactivates muscles that have shrunk in shoes, reactivates nerve endings, balances system, stimulates reflex massage at the bottom of the feet and even has anti- inflammatory benefits by shielding **[20]**.

Foot and Ankle Disability Index

The FADI specific questionnaire for foot and ankle consists in a total of 26 items, grouped into three different categories of questions: 16 items (1-16) related to walking, 6 items (17-22) to daily activity and 4 (23-26) to pain. Each item can be scored on a 5-points Likert scale (from zero to four), with a maximum total score of 104 points; the score can be transformed into percentage if a comparison with other questionnaires is needed.

The best possible score (104) corresponds to a complete absence of any difficulty in daily activities and no pain; the minimum score of zero (0) corresponds to the worst possible condition i.e. severe limitation in walking and daily activities as well as pain presence **[21]**.

Vertical Jump Test

Vertical jump test measuring the difference between a person's standing reach and the height to which he or she can jump and touch. The basic Sargent jump has the athlete stand facing a smooth, dark wall with both feet flat on the floor and toes touching the wall. He or she then reaches as high as possible with either hand and makes a mark on the wall (or wall-mounted jump board/chalkboard) with a piece of chalk or

chalk dust. Holding the desired jump position with the preferred side to the wall, the athlete then jumps as high as possible and makes another mark at the peak of the jump **[22-24]**.

One Leg Long Jumping Test

One-legged long jumping was evaluated on the basis of the measurement method used for the standing broad jump in the new physical strength test used by the Ministry of Education, Culture, Sports, Science and Technology, Japan. In this test, a tape measure was used to measure the distance from the toes to the heel of the measured lower limb. The measurements were collected twice for the left and right lower limbs, and the mean values for these measures were used **[25]**.

2. MATERIALS AND METHODS

➢ MATERIALS

- Assessment form
- Consent form
- Pen/ Paper
- Plastic tray with ink for foot print
- Cotton
- Chalk
- Measuring tape
- Bosu ball

➢ METHDOLOGY

A total of 150 individuals from Parul University were screened for flat foot using Navicular drop test – start position was in sitting and value of navicular drop was measured in standing and Berkemann footprint out of which 120 individuals were falling into the inclusion criteria who were recruited for the study. Once the recruitment was done all the individuals were asked to sign the written consent form. After signing the consent form these individuals were divided into 2 groups (group A & Group B) using a computer-generated randomization method.

Once the individuals were allocated to the groups, all the individuals were pre assessed for outcome measures for foot functions and disability on the basis of FADI and Dynamic parameter using one legged long jumping and vertical jump test before starting the intervention.

Details of the exercise intervention were as follows:

Table 1: Group A: Strength training for intrinsic flexor muscles

Level 1 (in sitting)	**Step 1 – Great toe extension and bring back to normal Step 2 – Extension of other toes bring back to normal Repeat to above steps and then do fanning of other toes & squeezing of toes**
Level 2 (in standing)	**Step 1 – Great toe extension and bring back to normal Step 2 – Extension of other toes bring back to normal Repeat to above steps and then do fanning of other toes Squeezing of toes**

Table 2: Group B: Bare foot weight bearing exercises + Strength training for intrinsic flexor muscles

EXERCISES	WEEKI	WEEKII	WEEKIII	WEEKIV	SETS (1 min. rest betweensets)
Squats (fig. 3.10)	10 Reps.	20 Reps.	10 Reps. On bosu ball	20 Reps. Onbosu ball	3
rward lunges(fig. 3.11)	10 Reps.	20 Reps.	10 Reps. On bosu ball	20 Reps. Onbosu ball	3
Side lunges(fig 3.12)	10 Reps.	20 Reps.	10 Reps. On bosu ball	20 Reps. Onbosu ball	3
Duck walks(fig 3.13)	20 Steps	30 Steps	40 Steps	50 Steps	3

STATISTICAL ANALYSIS:

The statistical software used for the analysis of data was SPSS version 25 (IBM). Microsoft Word and Excel was used to create the graphs and tables.

ETHICAL CLEARANCE:

In the act of research consists of human subjects, ethical clearance was acquired from ethical committee of Paul University Institutional Ethical Committee for human research (PUIECHR/PIMSR/00/081734/5803).

3. RESULT

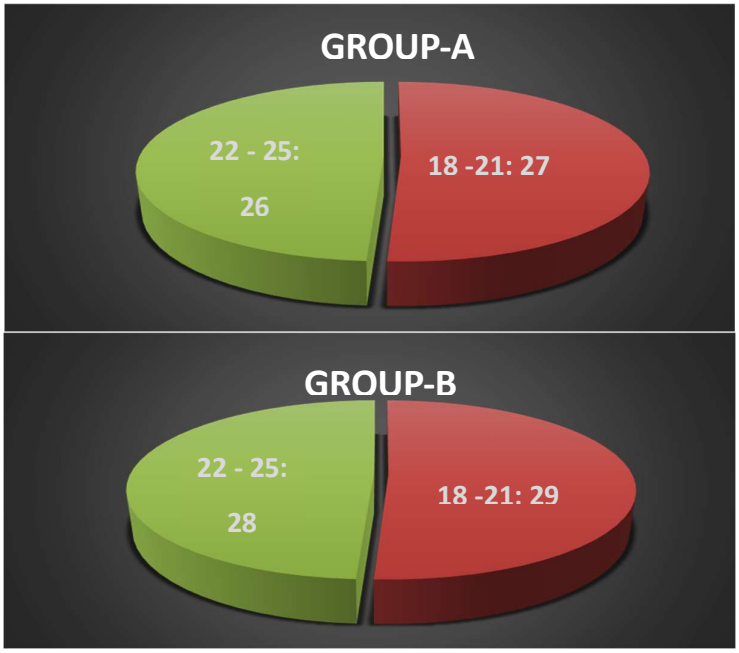
The 120 participants were included in the study and 109 completed the study on which statistical tests were performed.

STATISTICAL TESTS:

- The test of normality was done to know whether the obtained data is following normal distribution or not.
- Shapiro-Wilk test was used to check the normality and it was found that the data didn't follow the normality.
- Descriptive analysis was done for age, FADI, VJT and OLLJ was done to get mean and SD.
- As the data didn't follow the normality, Wilcoxon signed-rank test for paired samples (pre- and post-intervention comparison within the same group).
- Mann Whitney U Test was used to compare between the two groups (Independent Groups).

Table 3: The age distribution of the data is as follows:

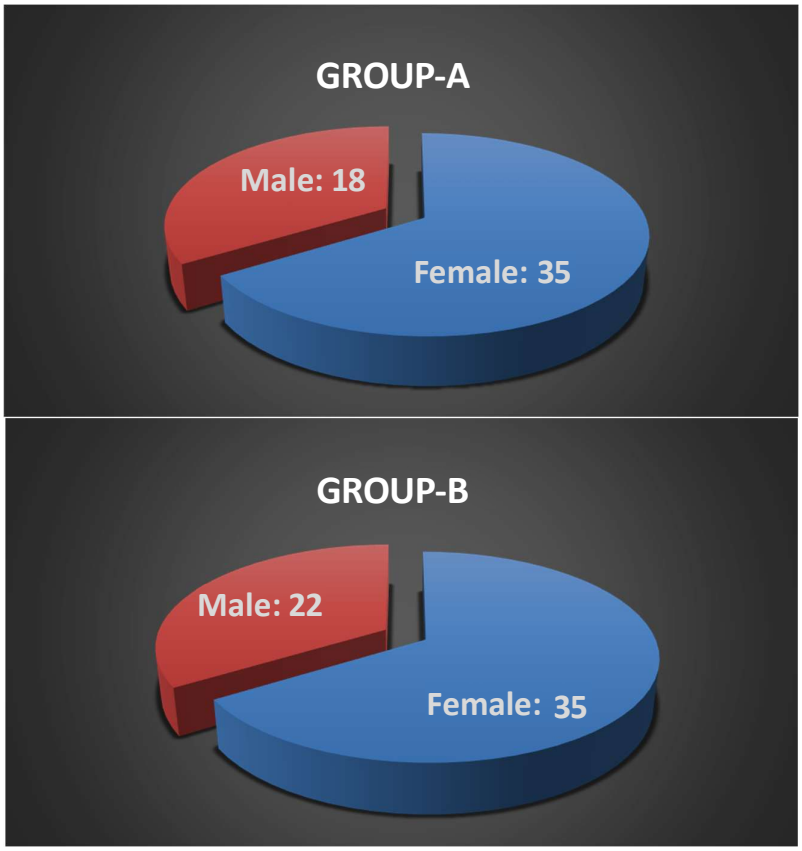
Age	GROUP-A	GROUP-B
18 -21	27	29
22 - 25	26	28



Graph 1: Pie Chart for Age Distribution of Group A and B

Table 4: Gender Distribution of both the Groups

Gender		
	Group A	Group B
Female	35	35
Male	18	22

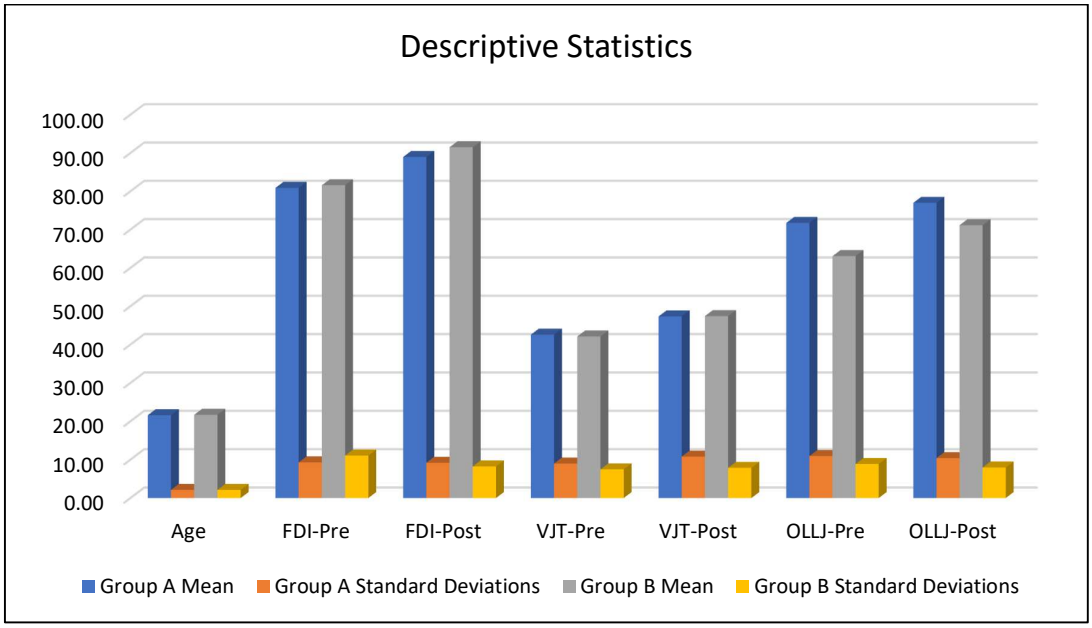


Graph 2: Pie chart shows the gender distribution in both the groups

The descriptive statistics **Table 3, 4** provides a comprehensive overview of key variables for participants in Group A and Group B. In terms of age, the mean age is 21.60 years with a standard deviation of 2.12 and 21.70 years with a standard deviation of 2.11 for Group A and B respectively, indicating a similar age distribution between the two groups. Regarding foot function, the Foot Disability Index (FDI) scores show an increase from pre- to post-intervention in both groups, with Group A demonstrating a mean FDI-Pre score of 80.91 (SD = 9.29) and Group B with a mean of 81.60 (SD = 11.08). Post-intervention, the mean FDI-Post scores are 88.96 (SD = 9.20) for Group A and 91.51 (SD = 8.25) for Group B. For dynamic parameters assessed by the Vertical Jump Test (VJT) and One-Leg Long Jump Test (OLLJ), Group A and Group B exhibit similar patterns of change from pre- to post-intervention.

Table 5: Wilcoxon Signed Rank Test to compare within group

Related-Samples Wilcoxon Signed Rank Test Summary					
	Outcome Measures	**Test Statistic**	**Standard Error**	**Standardized Test Statistic**	**Asymptotic Sig. (2-sided test)**
Group A	**FADI-PRE-POST**	**1431.000**	**111.534**	**6.415**	**0.000**
	VJT-PRE-POST	**990.000**	**85.331**	**5.801**	**0.000**
	OLLJ-Pre-post	**1431.000**	**112.170**	**6.379**	**0.000**
Group B	**FADI-PRE-POST**	**1653.000**	**125.309**	**6.596**	**0.000**
	VJT-PRE-POST	**1653.0**	**124.245**	**6.65**	**0.000**
	OLLJ-Pre-post	**1653.000**	**124.814**	**6.622**	**0.000**



Graph 3: Bar diagram to show mean and standard deviation of the data

The results demonstrate highly significant changes in all assessed variables within both groups. Specifically, for Group A, the Foot Disability Index (FADI-PRE-POST) exhibited a test statistic of 1431.000 with a standardized test statistic of 6.415 ($p < 0.001$).

Similarly, the Vertical Jump Test (VJT-PRE-POST) and One-Leg Long Jump Test (OLLJ-PRE-POST) in Group A showed significant test statistics of 990.000 ($p < 0.001$) and 1431.000 ($p < 0.001$), respectively. In Group B, the test statistics for FADI-PRE-POST, VJT-PRE-POST, and OLLJ-PRE-POST were 1653.000 ($p < 0.001$), 1653.0 ($p < 0.001$), and 1653.000 ($p < 0.001$), respectively.

These results indicate substantial improvements in foot function (FADI) and dynamic parameters (VJT, OLLJ) within both groups post-intervention, supporting the effectiveness of the interventions in enhancing foot-related outcomes.

Table 6: Comparison between two groups of outcome measures

Independent-Samples Mann-Whitney U Test Summary						
	Mann-Whitney U	**Wilcoxon W**	**Test Statistic**	**Standard Error**	**Standardized Test Statistic**	**Asymptotic Sig.(2-sided test)**
FADI	**1781.50**	**3434.50**	**1781.50**	**164.69**	**1.65**	**0.10**
VJT	**1557.000**	**3210.000**	**1557.000**	**164.427**	**0.283**	**0.777**
OLLJ	**2190.500**	**3843.500**	**2190.500**	**164.340**	**4.138**	**0.000**

The Mann-Whitney U test for FADI and VJT did not reveal a significant difference between Group A and Group B in terms of foot and ankle disability index and vertical Jump Test scores and ($p = 0.10$ and 0.77). Although the standardized test statistic suggests a moderate effect size, the result did not reach statistical significance. Both groups demonstrated comparable improvements in foot disability index scores, with no clear indication of one group having a superior outcome over the other.

For OLLJ indicated a significant difference between Group A and Group B in One-Leg Long Jump Test scores ($p < 0.001$). The high standardized test statistic (4.138) suggests a substantial effect size, and the result is statistically significant. Group A demonstrated greater improvements in One-Leg Long Jump performance compared to Group B, indicating that the intervention had a more pronounced positive impact on dynamic stability and lower limb strength in Group A.

4. DISCUSSION

Improvement in Group A – (Short foot exercise)

In group A, Short foot exercise for strength training for intrinsic flexor muscles of the foot is done, mean score for before the treatment of FADI was 80.91, VJT was 42.58 and OLLJ was 71.74 and after treatment for FADI was 88.96, VJT was 47.34 and OLLJ was 77.00 respectively.

Previous study done by Takayuki Hashimoto and Keishoku sakuraba states that there is significantly improvement in muscle strength scores, foot arch shape, and movement performance also states that intrinsic foot flexor strength training is useful for improving standing and walking performance, in addition to improving the performance of sports athletes engaged in activities involving greater exercise loads **[25]**.

Another study conducted by Eun-Kyung Kim *et al* suggested that "short foot exercises and arch support insoles improved flatfoot conditions and it could be seen that as the medial longitudinal arch was improved, dynamic balance ability was improved. In addition, it could be seen that sensory-motor training such as short foot exercises were more effective than conservative treatment methods such as arch support insoles **[7]**.

In this present study there is significant improvement in foot function and dynamic parameters of the individuals having flatfoot after having the treatment with short foot exercise. Previous study done by Abbis H. Jaffri *et al* outlined the usefulness of IFM strengthening in clinical populations. The clinical and functional benefits of using IFM exercises in rehabilitation of the lower extremities include improving balance, strength, and somatosensory function and decreasing ND, pain, and disability. Implementation of IFM exercises has also been shown to improve PRO's.

Improvement in Group B – (Barefoot weight bearing exercise combined with strength training for intrinsic flexor muscle)

The Group B was treated with barefoot weight bearing exercises combined with intrinsic flexor muscle strengthening – squats, forward lunges, side lunges and duck walk after 2 weeks of intervention all exercises are done on the bosu ball. Mean score for before the treatment of FADI was 81.60, VJT was 42.12 and OLLJ was 63.09 and after treatment for FADI was 91.51, VJT was 47.44 and OLLJ was 71.16 respectively.

Previous study done by Sharath Hullumani V ststes that barefoot activity and exercises were related to sensory stimulation will create a protective increase in muscle tone that can raise the arch. In present study barefoot exercises shows significantly improve in foot function and dynamic function with 4 weeks of intervention **[21]**.

Both groups demonstrated comparable improvements in foot and ankle disability index scores and Vertical jump, with no clear indication of one group having a superior outcome over the other. There is greater improvements in Group A for One-Leg Long Jump performance compared to Group B, indicating that the intervention had a more

pronounced positive impact on dynamic stability and lower limb strength in Group A.

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6. CONCLUSION

The present study was aimed to check the "effect of strength training for intrinsic flexor muscles of the foot versus barefoot weight bearing exercise on foot function and dynamic parameter among individuals with flat feet. Based on result it is concluded that there was significant improvement in both the groups for foot function and dynamic parameters that is FADI and VJT hence it accepts the null, hypothesis, but for OLLJ both groups were compared, Group A was found to be more effective than Group B, hence it accepts alternative hypothesis and rejects the null hypothesis.

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