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Comparision Between Muscle Strength of Plantar Flexors, Dorsi Flexors, Invertors, Evertors, Toe Grip Strength, and Flexibility of Ankle In Individuals with Neutral Foot and Flatfoot

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ABSTRACT

BACKGROUND: The arch construction is described as high, normal, or flat. Flatfoot develops when the medial longitudinal arch declines. Muscle strength of foot i.e., plantar flexors, dorsiflexors, invertors, evertors, toe grip strength and flexibility of ankle are important elements to aid in injury prevention, support functional movements, maintain foot posture, and promote overall health. Addressing muscle imbalances, flexibility deficits, and weakness through strengthening, stretching, balance training, orthotics, and functional exercises to reduce pain, improve gait, and promote long-term function.

OBJECTIVE: The study aims to compare the muscle strength of the plantar flexors, dorsiflexors, invertors, evertors, toe grip strength, and ankle flexibility in those with flatfoot and those with neutral foot.

MATERIALS AND METHODS: Thirty healthy students aged 20 to 24 years participated in the research. Two groups of participants were formed based on their NDT [Navicular Drop Test]. If the NDT value was lesser than 8mm, then those students allocated to group A, i.e., neutral foot and if it was greater than 8mm then, the students were in group B, i.e., flatfoot. Plantar flexors, dorsiflexors, invertors, evertors strength was assessed using the push pull dynamometer, and toe grip strength was assessed using the pinch gauge dynamometer. Flexibility of ankle was evaluated using the weight bearing lunge test.

STASTISTICAL ANALYSIS: The statistical analysis was done using SPSS 23.0. Frequency and percentage were used to express the category variables. The standard deviation and mean were used to display numerical variables. Based on the criterion of mean >2SD, the data is approximately normally distributed and hence comparision between the groups were carried out by the unpaired t test. P values less than 0.05 were regarded as statistically significant.

RESULTS: The mean value of muscle strength of plantar flexors, dorsiflexors, invertors, evertors, and toe grip strength, and also weight bearing lunge test is higher in group A when compared to group B. There is significant difference between muscle strength of plantar flexors, dorsiflexors, invertors, evertors, with **$p < 0.001$** for all comparisons and toe grip strength with a **t-value of 6.405** and **$p < 0.001$**, indicating the strength is significantly more in neutral foot when compared to flat foot. The weight bearing lunge test score was also significantly more in neutral foot when compared to flat foot with a **t-value of 7.897** and **$p < 0.001$**.
CONCLUSION: Muscle strength of plantar flexors, dorsiflexors, invertors, evertors, and toe grip strength is comparatively higher in neutral foot and weight bearing lunge test measurement is comparatively less in flatfoot, indicating that neutral foot have better muscle strength and flexibility of ankle.

KEYWORDS: Flatfoot, flexible flatfoot, flexibility of ankle, injury prevention, medial longitudinal arch, muscle strength, navicular drop test, neutral foot.

INTRODUCTION

As the link between the body and the ground, the foot is one of the most intricate and vital components of the body with respect to of mobility. It absorbs impact during activities such as walking and jumping and provides stability during push-off. In order to absorb shock and preserve healthy foot function, the medial longitudinal arch's function is essential. Arches refer to the height of the arch; and feet are classified as high, normal, or flat. Consequently, persons with flatfoot often have increased calcaneal eversion, forefoot valgus and pronation. Conversely, where there are high arches, there usually is supination and calcaneal inversion. The differences in foot mechanics in turn affect foot function and movement overall.[1]

Extrinsic and intrinsic muscles work together to control the foot arch's mobility and stability. These actions are supported by the extrinsic muscles flexor hallucis longus and tibialis posterior, which aid in ankle motions and balance, and the intrinsic muscles quadratus plantae as well as abductor hallucis, which stabilize the foot arch. Arch collapse and instability can result from overworking or overstretching of intrinsic muscles as the result of flatfoot and weakness in extrinsic muscles such as the tibialis posterior causing further arch collapse and instability. This condition can alter hind foot alignment, and soft tissue stability, possibly resulting in tibialis posterior insufficiency, affecting everything from the hind foot to the entire lower extremity.[2]

The range of motion (ROM) of the muscles, tendons and ligaments around the foot and ankle is the ankle's range of motion. Additionally, the subtalar joint's motion is mentioned. Proper flexibility allows the foot to adapt to various surfaces, absorb impact effectively, and generate enough propulsion during stride. The flexibility of the ankle and arch are important because the flexibility of the foot's arches facilitates movements.[3] In flexible flatfoot, the arch can be seen when foot heel is elevated and no weight is applied, but returns to normal when the foot is not bearing weight. People with rigid flat foot have limited ankle flexibility because their arch does not change shape, even when they are not bearing weight.[4]

Ankle flexibility in flatfoot is far more complicated than just a longitudinal arch's absence or depression. The foot's plantar-medial border is either convex or straight. The lateral margin is either concave or straight. When bearing weight, the midfoot sags creating contact with the ground. The weight-bearing axis in the lower extremities passes medially over the mid-axis on the hind foot, and the foot looks externally rotated with respect to the leg. The alignment of the hind foot called valgus. [5]

Muscle strength and flexibility are important components of total foot health, as they influence how the foot and lower limbs perform during dynamic exercises. The interaction of these two variables is especially significant in disorders like flatfoot, where muscle weakness and limited flexibility can exacerbate the problem. Addressing muscle imbalances, flexibility deficits, and weakness through strengthening, stretching, balance training, orthotics, and functional exercises to reduce pain, improve gait, and promote long-term function.[6]

This study aims to explore the link between muscle strength of plantar flexors, dorsiflexors, invertors, and evertors, strength of toe grip and ankle flexibility in people with flatfoot and neutral feet. If a positive connection found, early training programs targeting muscle strength and flexibility of ankle can improve overall movement quality, performance, injury prevention, performance enhancement, and rehabilitation. This knowledge for assessing overall movement quality and functional capacity, which are critical for daily activities and sport participation. Identifying approaches for reducing musculoskeletal problems and quality of life improvement constitutes another application.

METHODOLOGY

Screening subjects and grouping them

The **Navicular Drop Test [NDT]** was used to evaluate height of foot arch and describes arch construction with normal body mass indexes belonging to the age group of 20–24 years. The study enrolled 30 participants distributed across two distinct groups with 15 members each. Those having a history of recent trauma, musculoskeletal or neurological pain, and individuals with a history of injury or surgery on the lower extremities within the last six months, and undergoing physiotherapy or medical treatments were excluded. The subjects' age, height, weight and body mass index were also recorded by it. The push-pull dynamometer was used to assess the muscle strength of plantar/dorsiflexors, invertors/evertors and toe grip strength using a pinch gauge dynamometer and the flexibility of the ankle of the subject was assessed by using a weight-bearing lunge test [WBLT].

It was documented that all subjects were instructed on how to perform the tests. For each test, they were given one trial to become familiar with the techniques and procedures. Before each test, a 2–5 m rest period was allowed.

Outcome measures;

Assessment of muscle strength [plantar flexors, dorsiflexors, invertors, evertors, and toe grip strength]

Subjects were instructed to sit with the ankle at a neutral position and the knee flexed to 90 degrees. Participants were instructed to push their feet downward **(plantarflexion)** and upward **(dorsiflexion)**. To provide resistance on the bottom surface of the foot during plantarflexion, a push-pull dynamometer was positioned at the midfoot or behind the metatarsal heads. For dorsiflexion, the dynamometer was positioned on the upper surface of the foot, either at the heads of the metatarsals or midfoot[7]. The subjects were seated, with their ankles neutral or slightly dorsiflexed and their knees slightly flexed. Both foot **inversion** (sole turning inward) and **eversion** (sole turning outward) were required of them. In order to apply lateral resistance for inversion, a dynamometer was placed on the foot's medial side; for eversion, the dynamometer was positioned on the lateral side. This test was performed 2-3 times for each movement[8].

Subjects should be seated comfortably with their feet resting on a flat surface, with their toes gripping or pinching a target. A pinch gauge is used to determine the force of the toe grip. The individual is instructed to hold as tightly as possible without using their knee or hip muscles. The maximal force exerted by the toes is recorded. This method can be repeated for each toe or across several trials (e.g., three trials) to obtain an average reading, which can then be compared for each toe or overall toe grip strength.[9]

Assessment of flexibility of ankle

Ankle flexibility is assessed using the **Weight-Bearing Lunge Test (WBLT)**.Participants in the test stand facing the wall with the second toe, heel, as well as knee perpendicular to the wall, and one foot parallel to the measuring tape. Hands are put on the wall, and the other foot is positioned behind a test foot in a suitable stance for balance. After that, participants lunge, keeping their heel in the ground and striving to touch the barrier with their knee. Until the participant is unable to sustain heel and knee contact, the test is repeated by gradually removing the test foot from the wall by 1 cm. To the closest 0.1 cm, the greatest lunge distance is recorded. The normal value for this test is 12.5 cm. The test is repeated on both legs to compare ankle flexibility.[10]

STATISTICAL ANALYSIS

Statistical Methods

Age, height, weight, BMI, and gender were among the demographic data that were compiled using descriptive statistics. The statistical analysis was done using **SPSS 23.0**. Frequency and percentage were used to express the category variables. The standard deviation and mean were used to display numerical variables. Based on the **criterion of mean >2SD**, the data is approximately normally distributed and hence comparision between the groups were carried out by the **unpaired t test**. **P** values **less than 0.05** were regarded as **statistically significant.**

Table 1: Demographic Data

	Neutral foot	Flat foot
	Mean±SD/f (%)	Mean±SD/f (%)
Age	21.46±1.68	20.73±2.54
BMI	25.191±3.552	21.593±3.363
Gender		
Female	9(60%)	11(73.3%)
Male	6(40%)	4(26.7%)

The study involved two groups: a **neutral foot** and a **flat foot**, with a total of 15 participants in each. Participants in the flat foot group were **20.73 ± 2.54** years old, whereas those in a neutral foot group were **21.46 ± 1.68** years old. The mean body mass index (BMI) for the neutral foot was **25.19 ± 3.55 kg/m²**, compared to **21.59 ± 3.36 kg/m²** in the flat foot. Regarding gender distribution, the neutral foot comprised **9 females (60%)** and **6 males (40%)**, while the flat foot had **11 females (73.3%)** and **4 males (26.7%)**.

Table 2: Comparison of Plantar flexors, dorsiflexors, invertors, evertors

		Type of foot	N	Mean	Std. Deviation	t value	p value
PLANTAR FLEXORS	Right	Neutral foot group	15	35.567	6.302	2.879	p<0.001
		Flat foot group	15	28.567	7.000		
	Left	Neutral foot group	15	35.300	6.313	2.805	p<0.001
		Flat foot group	15	28.400	7.134		
DORSIFLEXORS	Right	Neutral foot group	15	25.673	3.167	4.473	p<0.001
		Flat foot group	15	19.567	4.234		
	Left	Neutral foot group	15	24.733	3.575	3.780	p<0.001
		Flat foot group	15	19.300	4.267		
INVERTORS	Right	Neutral foot group	15	18.633	3.507	3.442	p<0.001
		Flat foot group	15	14.600	2.880		
	Left	Neutral foot group	15	18.333	3.663	3.351	p<0.001
		Flat foot group	15	14.300	2.883		
EVERTORS	Right	Neutral foot group	15	19.767	3.565	3.293	p<0.001
		Flat foot group	15	15.700	3.189		
	Left	Neutral foot group	15	19.333	3.634	3.371	p<0.001
		Flat foot group	15	15.133	3.176		
TOE-GRIP STRENGTH	Right	Neutral foot group	15	8.267	0.884	7.442	p<0.001
		Flat foot group	15	5.967	0.812		
	Left	Neutral foot group	15	7.767	0.923	6.405	p<0.001
		Flat foot group	15	5.600	0.930		

For **plantar flexors**, the **right side** exhibited a mean strength of **35.57 ± 6.30 kg** in the neutral foot and **28.57 ± 7.00 kg** in the flat foot. On the **left side**, the neutral foot had a mean strength of **35.30 ± 6.31 kg**, while the flat foot showed **28.40 ± 7.13 kg**.

In the neutral foot, the mean strength value of **dorsiflexors** on the **right side** was **25.67 ± 3.17 kg**, while on the flat foot; it was **19.57 ± 4.23 kg**. The mean strength on the **left side** was **24.73 ± 3.58kg** in the neutral foot and **19.30 ± 4.27 kg** in the flat foot.

Regarding the **invertors** side, it was found that there was a mean compressional strength of **18.63± 3.50 kg** in the neutral foot **14.60± 2.88 kg** in the flat foot for the **right side**; **18.33± 3.66 kg** in the neutral foot, and **14.30± 2.88 kg** in the flat foot for the **left side**.

As far as **evertors** are concerned, the mean strength on the **right side** was **19.77 ± 3.57 kg** (neutral foot) and **15.70 ± 3.19 kg** (flat foot). The mean value of the flat foot side was **15.13 ± 3.18 kg** compared to **19.33 ± 3.63 kg** for the neutral foot on the **left side**.
The mean **toe grip strength** for the **right side** of the neutral foot group was **8.27 ± 0.88 kg,** and for the **left 7.77 ± 0.92 kg**. In contrast, the flat foot group showed significantly lower values of **5.97 ± 0.81 kg** on the **right side** and **5.60 ± 0.93 kg** on the **left side.**
Overall, the results indicate that muscles strength was significantly greater in the neutral foot across all muscle group—**plantar flexors, dorsiflexors, invertors, evertors, and toe grip strength**—compared to the flat foot, with **p < 0.001** for all comparisons.

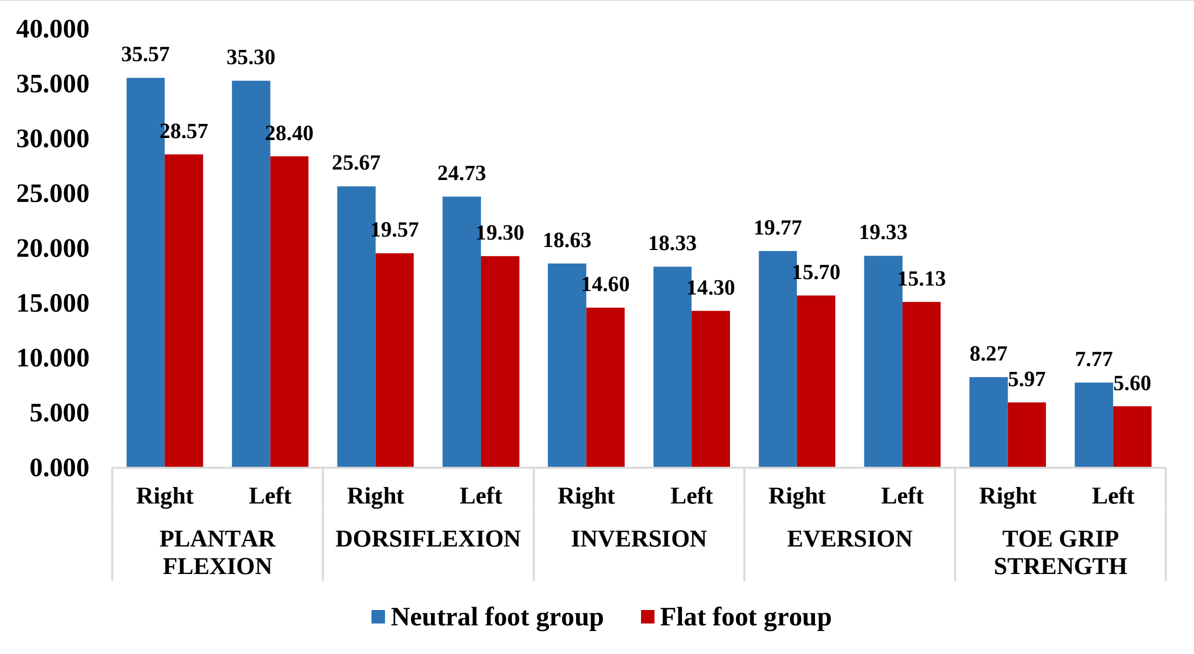
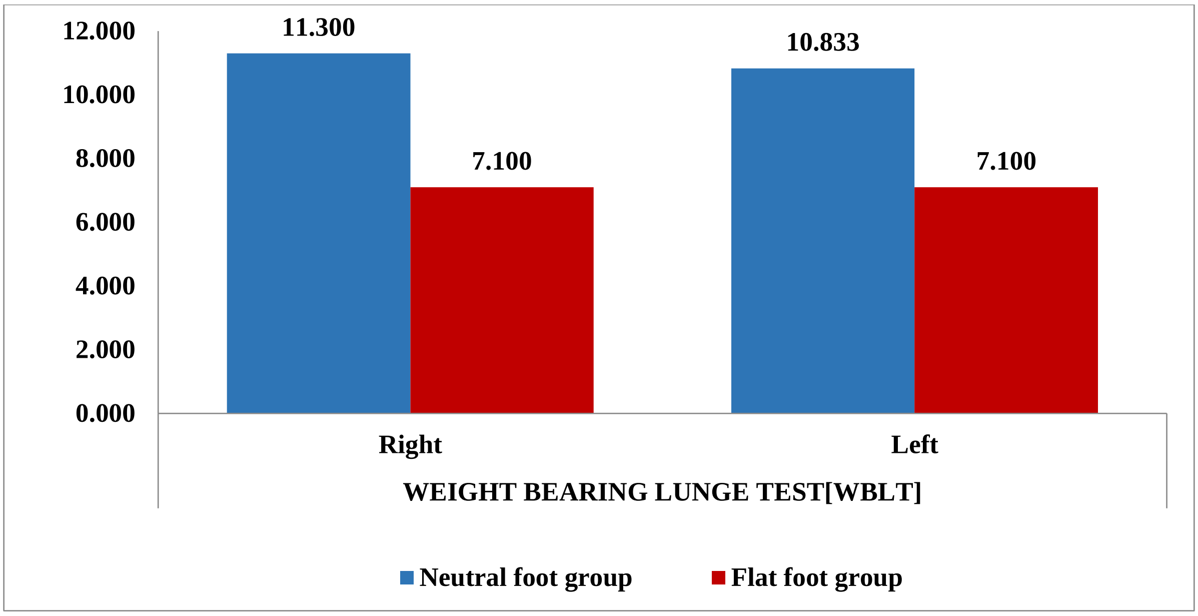


Table 2: Comparison of WEIGHT BEARING LUNGE TEST [WBLT]

Side	Type of foot	Mean	Std. Deviation	t value	p value
Right	Neutral foot	11.300	0.862	10.144	p<0.001
	Flat foot	7.100	1.352		
Left	Neutral foot	10.833	1.113	7.897	p<0.001
	Flat foot	7.100	1.454		

The **Weight Bearing Lunge Test (WBLT)** was used to assess flexibility on both the right and left sides in participants from the **neutral foot** and **flat foot**. The mean WBLT score for the neutral foot was **11.30 ± 0.86 cm** for the **right side** and **7.10 ± 1.35 cm** for the latter was substantially lower **(p < 0.05)** than for the flat foot. The mean WBLT score from the neutral foot on the **left side** was **10.83 ± 1.11 cm**, and in the flat foot, it was **7.10 ± 1.45 cm**. Analysis reveals that there is a statistically significant large difference as the **WBLT** score in the Neutral foot is greater than that of the flat foot **(t = 7.897, p < 0.001).**



DISCUSSION

People with flat feet were found to have less ankle flexibility and weaker plantar flexors, dorsiflexors, invertors and evertors, and toe grip strength as compared to people with neutral feet. Overstretched or broken muscles, as well as decreased ankle dorsiflexion[11] associated with stiff calf muscles or tendons that can also lead to the collapse of the MLA, may cause this weakness — especially in flexible flatfoot. Those with flatfoot are often compensating for this lack of motion and therefore often use excessive pronation. This can worsen foot abnormalities and create more musculoskeletal problems in the pelvis or lower limbs.[12]

All studies on the effect of muscle strength of plantar flexors, dorsiflexors, invertors, evertors, toe grip strength and flexibility of ankle on persons with neutral foot and flatfoot. They also found that certain combinations of foot posture and rotations or variances of the ankle dorsiflexion and there was a correlation between the peak pressure distribution, strength of the plantar flexor, invertor, and evertor muscles, gastronemius and soleus muscle flexibility, and eversion range of motion. Given these results, supinated foot athletes should work out to increase foot mobility, the strength of evertor muscles as well as the flexibility of muscles gastronemius and soleus.[13]

The propulsive task function of intrinsic foot muscles, extrinsic foot muscles, and ankle plantar flexors was investigated with specific attention devoted to vertical jump performance by Eriksen Daehlin et al. The foot muscles, while not jumping muscles per se, are necessary to preserve the foot's arch and help the ankle's plantar flexors raise a jump's real height, as their research demonstrates. The study goes on to say that preventing the triceps surae muscles from deforming the foot arch should be possible by strengthening extrinsic and intrinsic foot muscles. While heel rises and other exercises like these do improve toe flexor strength and jump height, it is not known exactly why. Tomoaki Kamiya et al. proposed that the tibialis posterior muscle's dynamic force was necessary to preserve and raise the medial longitudinal arch's height in the face of cyclic axial stress. According to their findings, the tibialis posterior's dynamic force is essential for preserving and raising the medial longitudinal arch's height under load. They imply that even in the absence of flatfoot deformity, it is crucial to assess the function of that muscle, particularly in situations of medial ankle pain. Additionally, activities involving dynamic weight bearing, like long walking, may increase the risk of arch collapse in individuals with tibialis posterior tendon dysfunction.[14] Yuki Kusagawa et al. suggested that TFS [Toe Flexor Strength] would be linked to mobility, namely walking performance, among older women who had pronated as well as supinated feet rather than neutral feet, highlighting the importance of the toe flexor muscle. i.e. flexor hallucis longus strength in flatfoot[15].

Researchers also found that flatfoot be caused by a variety of reasons, including foot bone anomalies, foot muscle dysfunction or weakness, calf muscle contraction or tension, ligament laxity, and a shortened Achilles tendon. Additionally, pronated feet impair both muscle flexibility and strength, which may change the lower extremities' dynamic balance and muscular activity. Training these muscles for strength and flexibility can assist to cure flatfoot concerns and improve general foot health.

There are limitations to our study which included a relatively small size of 30 individuals with 15 in each group, whereas a larger sample size would have enhanced the statistical power of the study. In addition, the included studies utilized different methods for assessing muscles strength of plantar flexors, dorsiflexors, invertors, evertors, toe grip strength and flexibility of ankle. The method used is valid and reliable.

CONCLUSION

The research shows that there can be a notable variation in the muscle strength of plantar flexors, dorsiflexors, invertors, evertors, toe grip strength and flexibility of ankle between individuals with neutral foot and those with flatfoot. Enhancing muscle strength and flexibility of ankle is essential for young, healthy individuals. These elements are important for injury prevention, functional movements, maintaining proper posture and balance and addressing muscle imbalances, flexibility deficits, and weakness through strengthening, stretching, balance training, orthotics, and functional exercises to reduce pain, improve gait, and promote long-term function.

Declaration of the patient's consent

The authors attest to having obtained all necessary patients' consent for participation in this study. The patients have granted agreement for the utilization of their medical data to be included in this publication. Participants understand that their names and initials won't be used. Confidentiality of the participant’s personal and medical information was ensured throughout the study, and data was used strictly for research purposes.

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