EFFECT OF FLEXIBLE FLAT FOOT ON KNEE PROPRIOCEPTION AND POSTURAL STABILITY AMONG PHYSIOTHERAPY STUDENTS IN KARACHI: A CROSS-SECTIONAL STUDY

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ABSTRACT

Introduction: *Flexible flat foot alters foot biomechanics and proprioceptive feedback mechanism towards the central nervous system. As a result, an individual's joint position sense and balance can be affected, causing an increase in mechanical stress on musculoskeletal structures and chance of lower limb injuries and risk of fall.*

Objectives: *This study aimed to investigate the impact of flexible flat foot on knee proprioception and postural stability as well as the association among knee proprioception, static and dynamic stability.*

Methods: *This multicenter cross-sectional study was conducted in Karachi, Pakistan. For this, 94 physiotherapy students aged 18 to 25 years with flexible foot/feet were recruited. However, participants with rigid flat foot/feet, leg length discrepancy, congenital deformities, fractures, orthosis, foot and lower limb surgeries, or lower limb contractures were excluded. Participant's static stability and knee proprioception were assessed through the Sharpened Romberg test with eyes open and closed, respectively, while the Y-balance test was used for dynamic stability. Spearman's correlation coefficient was used to evaluate the impact of flexible flat foot on each variable and to assess the correlation between knee proprioception and postural stability.*

Result: *The Spearman's correlation analysis revealed that flexible flat foot and knee proprioception were negatively correlated (p = 0.277). However, a significant correlation was seen with both static (p = 0.031) and dynamic stability (p = 0.015). Moreover, the association between knee proprioception and postural stability was found to be statistically insignificant.* ***Conclusion:*** *Flexible flat foot impacts postural stability but does not significantly impact knee proprioception, necessitating rehabilitation techniques for improved quality of life and functional outcomes..*

INTRODUCTION

The anatomy of the human foot has a complex and intricate structure composed of 26 bones, 33joints, more than a hundred muscles, ligaments, tendons and distinguishable arches(1).The presence of arches in the foot have an essential role for the control of balance, stability and flexibility enabling us to perform a wide range of bipedal locomotion(2).Therefore, the dynamicity of the foot arches is essential for functions like shock absorption and the even distribution of body weight among the foot, therefore reducing pressure on specific areas contributing to optimum biomechanical efficiency(3). The human foot has a total of four arches divided into two longitudinal (medial and lateral arches) and two transverse (anterior and posterior arches)(2).

The transverse arches are supported by the attachment of the deep transverse ligament and the fibularis longus tendon at the metatarsals and are formed by the mid tarsal and the tarsometatarsal joint including the cuboid bone, cuneiform bone and the fifth metatarsal(4).Whereas, the lateral longitudinal arch is formed by the combination of the calcaneus, metatarsals and tarsals, supported predominantly by the longer planter ligament with minor assistance from the short plantar ligament(5). Moreover, the medial longitudinal arch, predominantly supported by the spring ligament, possesses greater height in comparison to the lateral longitudinal arch(6).During the initial heel strike phase of the gait cycle the transverse arches play a predominant role in midfoot stiffness while between loading response and midfoot stance there is a decrease of muscle tension causing an increase in the foot pronation and passive stretch as a consequence of which the longitudinal arches tend to deform(7, 8). This deformation mechanism is crucial for the storage of elastic energy within the surrounding ligaments, fascia, and foot muscles essential for the push-off phase in the gait cycle(4). Whereas, during push-off phase the windless effect occurs causing an increase in tension of the plantar aponeurosis muscle as the foot goes in plantarflexion, supination and extension of the metatarsal phalangeal joint this results in the increase of the arches(8).

Pes planus, also referred to as flat foot, presents with a noticeable reduction in the height of the medial longitudinal arch, resulting in the plantar surface of the foot making direct contact with the ground(9). Flat foot commonly manifests in infants, attributable to the presence of a fat pad beneath the medial longitudinal arch, serving as a protective mechanism during the early stages of childhood development(10). While it is typical for children to develop normal arches by the age of 6 or 7, a minority may not achieve this by adulthood(6). Acquired pes planus is frequently associated with conditions such as posterior tibial dysfunction, arthropathies, hind foot or midfoot trauma, and congenital ligamentous laxity seen in conditions like Down syndrome, Marfan syndrome, or Ehlers-Danlos syndrome(6, 11). However, the adult flat foot is usually associated with mechanical stress or structural loading along the medial side of the foot with collapse of the mid foot and rear foot these changes are usually diagnosed as an incidental finding with associated clinical symptoms of pain, muscle cramps and fatigue(11).

Flat foot can be classified into three types of categories according to the difference in height of medial longitudinal arch, in normal arched or pes rectus the height of medial longitudinal arch is(2.57 ± 0.14 cm), in pes planus or flat foot (1.86 ± 0.23 cm) and in pes cavus or high arched foot the measurement of height was considered to be (3.26 ± 0.16 cm)(12). Meanwhile, other researchers suggested that pes planus can be categorized into three distinct types: rigid flat foot, flexible flat foot, and flexible flat foot with a short Achilles tendon(3).

Previous studies show that flexible flat foot can cause modifications in the lower limb kinematic sand alignment including tibial internal rotation and torsion, internal rotation of femur, external hip rotation, pelvic anteversion, greater genu recurvatum, lumbar lordosis, anterior knee laxity, valgus of the knee and increase subtalar pronation(13, 14). Furthermore, it was observed in some studies that there was a significant decrease in the isometric strength of hip abductors, external rotators and quadriceps muscles while a prominent decrease was also seen in the isokinetic concentric strength of the hip flexors, extensors, internal rotators, and external rotators(15).These changes in the gait biomechanics are a contributing factor in various lower limb pathologies such as patellofemoral syndrome, soft tissue injuries like plantar fasciitis, patellar tendinitis, anterior cruciate ligament injuries and foot pain(14).

Physical therapy or exercises include different techniques to strengthen the surrounding structures of medial longitudinal arch comprising of anterior tibialis, posterior tibialis, peroneus longus muscle as well as the posterior tibial tendon(12). Moreover, the use of toe curl exercise or short foot exercises in previous studies has found to be beneficial in improving patient's postural stability by maximizing the strength of the intrinsic muscles of the foot such as abductor hallucis longus, interosseous muscles, flexor hallucis and flexor digitorum muscles(16, 17). Other methods for improving the quality of life in flat feet patients includes the use of kinesotaping, ankle bracing, contoured insoles, foot orthosis and the use of proper footwear that are beneficial in restoring proper foot alignment, muscular activity, functional activity as well as providing support and relieve in pain during ambulation(12).

The prevalence of flat foot among general population according to previous researches was found to be between 20% to 37%(12). Whereas, among children aged 3 to 6, the occurrence of flat foot ranges from 21% to 57%, as individuals age, the prevalence tends to diminish, with percentages decreasing to between 13.6% and 27.6%(18). Notably, among young adults aged 18to 25, the presence of flat foot is reported at 11.25%(3, 12). Despite limited amount of literature on the subject, a study conducted in Karachi, Pakistan, revealed a prevalence rate of 15.5%among young adults, underscoring the need for further research in this area(19).

The peripheral and central nervous systems work together to control the body's alignment and COG (center of gravity) within the BOS (base of support), allowing an individual to sustain equilibrium in an erect position(20). Therefore, the maintenance of postural stability (static and dynamic) is influenced by the CNS getting information from the sensory system of the body, the somatosensory (joint mechanoreceptors, epidermal external skin receptors, and muscle receptors), visual, and vestibular systems(20). Static postural stability is the capacity to maintain a stable standing posture over a stationary base of support(21). On the other hand, the capacity to shift and regulate how one's center of mass projects over a base of support when moving from a dynamic to a static state is known as dynamic postural stability(22).

Decrease in MLA (medial longitudinal arch) height reduces muscle strength, endurance, balance parameters, and the capacity of the body to withstand ground reaction forces(23). Therefore compromising the overall alignment and COG leading towards the inability to maintain BOS during static standing (24). On the other hand, dynamic stability is seen to be compromised during synchronize locomotor activity in both daily life and sports(25). The foot's dynamic stabilizers, both intrinsic and extrinsic, in addition to the medial longitudinal arch's static stabilizers, such as the plantar fascia and spring ligament play an important role in maintaining the postural alignment of the body. Previous studies have shown that improvement in the foot posture and stability can be achieved by activating these muscles(26).

The somatosensory system uses the CNS's base of support in order to collect information about the position and motion of the body(27). Proper sense of body position, comprehension of processed data, and conscious or unconscious reactions to stimuli demonstrating proper posture or movement are all considered aspects of proprioception, which comes from the Latin word "proprius", meaning one's own(28). In order to generate coordinated movements, learn and retrain motor skills, condition the body, and maintain balance, it is highly important. Proprioception is necessary for balance, walking, climbing stairs, and performing the sit-to-stand motion. Accurate neuromuscular control and proprioceptive acuity are essential for postural stability(29). The ability to feel an individual's joint position, sense joint movement, distinguish between various loads falling on the joints, and differentiate between motions of an individual's limbs is known as proprioceptive acuity(30). Proprioceptive signals are one of the sensory inputs obtained from various sensory systems that the central nervous system uses to create postural tone for this the sole's afferent input has the biggest impact on positional awareness(20).

Since sensory feedback is important to movement programming, abnormal proprioceptive signals impact both motor control as well as sensory function. Poor balance can negatively impact one's quality of life as it is one of the "abilities" that is most affected by wrong proprioception(31). Three key components of balance control are muscle strength, cutaneous sensitivity, and proprioception. Proprioception, cutaneous sensitivity, and muscle strength work together as the primary components that brain networks use to regulate peripheral balance(32). Muscle lengthening is triggered by stretched muscle spindles when a disruption happens. As a result, proprioceptive information is generated on afferent fibers, which can then send proprioceptive information to the sensorimotor cortex and cerebellum or make synapses with α motor neurons and interneurons. At the same time, the central nervous system (CNS) receives information relating to pressure and vibration via cutaneous mechanoreceptors, which facilitates comparisons of the stimuli in terms of both time and space(32).

The impairment in the vestibular, somatosensory, and proprioceptive systems increases the risk of falling because it impairs knee joint control and balance. Threshold to perception of passive movement and joint position sensing are the most often utilized proprioceptive measuring techniques(28). One intervention that has been shown to enhance knee proprioception is tai chi practice, which increases mobility, balance, and coordination. Age-related improvements in balance, mobility, and strength have been noted in relation to exercise combined with gaming(29, 33).

Proprioception can be measured for the knee joint in weight-bearing as well as non-weight-bearing positions. However, as the NWB knee relocation approach does not include movement, resistance, or weight bearing through adjacent joints, a growing number of authors have suggested using the weight bearing test of proprioception in recent years(27).

The biomechanical impact of the foot sole on the proprioceptive function of the lower limb joints has not received as much attention in research(34). Ankle isokinetic strength and proprioception were only tested in patients with flat feet the findings of which showed that, in comparison to the control group, individuals with flexible flat foot had significantly higher error scores for passive reproduction of ankle joint position in eversion on the dominant side and the strength of the evertor and invertor muscles did not significantly differ between the control group and those with flat, flexible soles(34). A study conducted to explore the effectiveness of flexible flat feet on static stability, ankle and knee proprioception concluded that those with flexible flat foot demonstrated significantly lower static balance, ankle, and knee proprioception than those with normal foot function as a result, it is unknown how the sole's biomechanical properties affect lower limb proprioception and balance(34). Another significant research and compare bilateral flexible flat foot subjects to normal subjects, weight-bearing proprioception examination gave more accurate and functionally related results than non-weight bearing assessment(27).

Therefore, according to above literature and findings it is important to understand postural instability and proprioceptive effects as a consequence of flat feet or flexible flat feet in order to provide efficient treatment techniques for improving an individual's quality of life, ability to perform better in physical or recreational activities and to be able to use different methods for relieving pain, muscle cramps and fatigue.

2. Methodology

This was a multicenter cross-sectional study. The targeted population of this study were physiotherapy students of Karachi. For this purpose, data was collected from various physiotherapy institutes and universities in Karachi, Pakistan, including Liaquat National School of Physiotherapy, Jinnah Sindh Medical University, Jinnah Postgraduate Medical Centre, Indus University, Hamdard University, University of Karachi, United Medical and Dental College and Bahria University. For the purpose of data collection, we used a convenience-based sampling method as it was more feasible and cost effective.

2.1 Sample Size

The estimated sample size was calculated through the WHO sample size calculator. The total sample size calculated was 545. This estimation was based on a prevalence of 15.5% obtained from a reference research (19), with a confidence interval of 95%. As the nature of this research was multicenter, the margin of error was considered to be 3%. However, only a sample of 94 was collected due to restriction of permission from universities as well as limited availability of time.

2.2 Inclusion Criteria

- Participant had to be registered in a physiotherapy program.
- Participant must be between the ages of 18 and 25.
- Participant must have flexible flat foot/feet as per the navicular drop test.

2.3 Exclusion Criteria

- Participant with rigid flat foot/feet.

- Participant with leg length discrepancy.
- Participant with any musculoskeletal and neurological conditions affecting balance.
- Participant with congenital deformities of foot and lower limb.
- Participant with history of fracture of lower limb.
- Participant with any orthosis or insoles.
- Participant with history of foot and lower limb surgeries.
- Participant with lower limb contractures.

2.4 Study Parameters

The data was collected in person and recorded in hard copy form. The demographic information was included in the consent form to maintain privacy. A semi-structured questionnaire was used, divided into two parts. The first part included seven brief close ended questions regarding participant's awareness of the term flexible flat foot, type of footwear they use, how long they wear it, and the amount of physical activity they perform in a week. The second part included three standardized, valid and reliable measurement tests.

2.4.1 FOR FLEXIBLE FLAT FOOT: NAVICULAR DROP TEST:

This test shows great reliability for assessing navicular height (interclass correlation coefficient [ICC]:>.94), according to earlier studies, with ICCs of .83 and.73 for intra- and inter-rater reliability, respectively(42). Before starting this test, the limb length of both lower extremities was measured starting from the ASIS to the distal border of the medial malleolus in standing position. The navicular drop test was performed in two positions. For the first measurement, the participant was asked to sit in a chair with knees bent to 90 degrees and feet in a non-weight-bearing position, following this the vertical distance from the ground to navicular tuberosity was measured. The same measurement was assessed while the participants were standing in a weight-bearing position. If there was a difference of more than 10 mm in the vertical height between the weight-bearing and non-weight-bearing positions, the participant was assigned to the flat foot group.

2.4.2 FOR STATIC STABILITY: SHARPENED ROMBERG TEST:

For the initial position of test, the participant had to stand barefoot in tandem position on a level surface. Than the participant was instructed to put forward their right leg in front of their left leg and stand in this position for 30 seconds with eyes open and then with eyes closed. The test was considered positive if the participant starts to sway in any direction within 30 seconds.

The same procedure was performed with left lower extremity in front of right lower extremity. The validity of this test was determined to be 0.76–0.77(20).

2.4.3 FOR DYNAMIC STABILITY: Y BALANCE TEST:

For this test the participant was asked to stand in a one-leg stance position first with their dominant leg on the platform. Then the participant was asked to move their non-dominant leg in anterior, posteromedial, and posterolateral directions. The same procedure was followed for the non-dominant leg assessment. A total of six measurements were taken for each direction, out of which the greatest value was recorded for each direction. The mean distances of all reach directions were then divided by limb length and multiplied by hundred for the final composite value. The composite score for this test was (< or = 97.89). Both the interrater and intrarater correlations in the Y Balance Tests (0.85–0.91) were excellent(16).

2.4.4 FOR KNEE PROPRIOCEPTION:

A positive result for knee proprioception was obtained by the Sharpened Romberg test if the participant sways or deviates from the stance position with the eyes closed.

2.5 Ethical Considerations

Participants were asked to sign an informed consent to ensure voluntary participation. All the risks and benefits regarding the study were guided to each participant with the right to withdraw during any step of the study. Each participant was assigned with a code number to maintain confidentiality. Moreover, the data was kept anonymous and no manipulation was done.

2.6 Data Analysis Procedure

The mean, standard deviation, minimum and maximum values were used for the representation of data. To evaluate the effect of flexible flat foot on all variables and to examine the relationship between knee proprioception and both static and dynamic stability, Spearman's correlation coefficient was used. Prior to conducting the test, the data's normality was examined using the Shapiro-Wilk test. A significance level of 0.05 was taken into account for all calculations. SPSS21 software was used for all statistical calculations.

Result

A total of 700 students were assessed for flexible flat foot through the navicular drop test out of which only 94 participants were recruited for this study based on a positive result. This data indicated that the prevalence of flexible flat foot among physiotherapy students in Karachi was found to be 13.4%.

The general features of the participants are summarized in (Table 1). The average age, height, and weight of the participants were 21.78 years, 1.615 meters, and 61.62 kilograms, respectively. The means of the left and right limb lengths were the same, measuring 33.846 cm, and their variability was comparable.

Variables	Mean	Std.deviation	Minimum	Maximum
Age (years)	21.78	1.63	19	25
Height (m)	1.615	0.081	1.42	1.87
Weight (Kg)	61.62	10.69	40	92
Right limb length (cm)	33.84	2.156	30	39.5
Left limb length (cm)	33.84	2.156	30	39.5

Table 1 General features of the participants

Out of 94 participants 87 individuals (92.5%) had bilateral flexible flat feet. A smaller proportion of individuals reported varying outcomes: 3 participants (3.2%) had only right flexible flat foot, while 4 participants (4.3%) had flexible flat foot solely on the left foot (Figure 1). A total of 92 participants (97.9%) showed significant impairment in knee proprioception. While, only 2.1% had normal knee proprioception (Figure 2). 74 out of 94 participants (78.7%) clearly showed indications of reduced static stability while only 20 individuals (21.3%) had a normal static balance (Figure 3). Total of 19 participants (20.2%) had a normal dynamic balance whereas 75 participants (79.8%) had a significantly reduced dynamic stability (Figure 4).

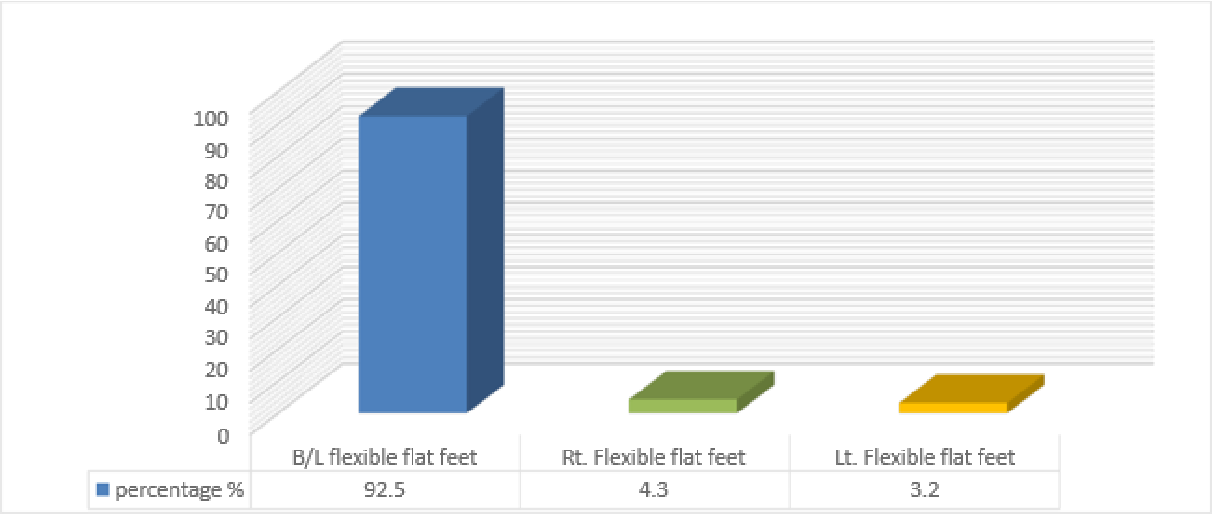

Figure 1 Participants percentage of flexible flat foot

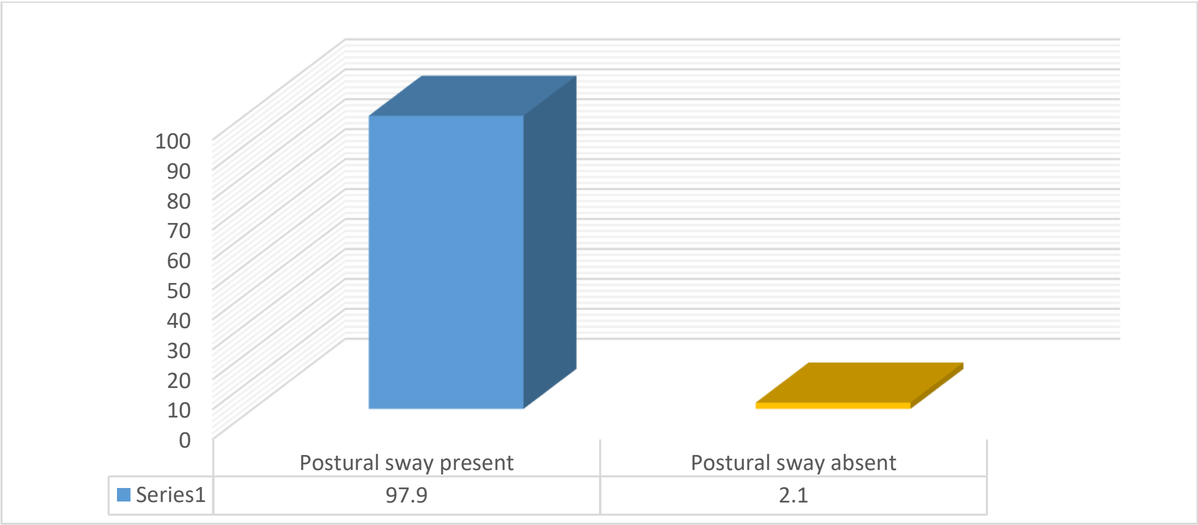

Figure 2 Percentage of knee proprioception

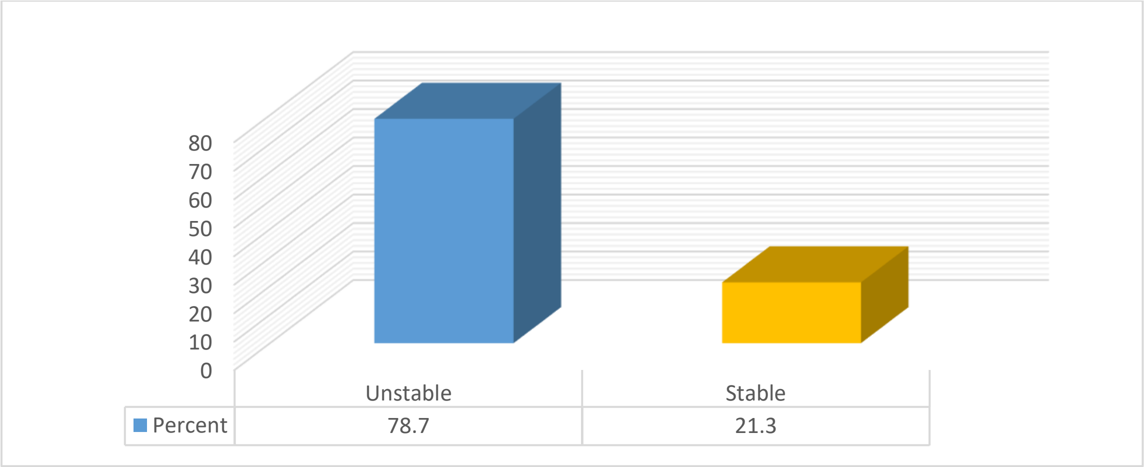

Figure 3 Percentage of static balance

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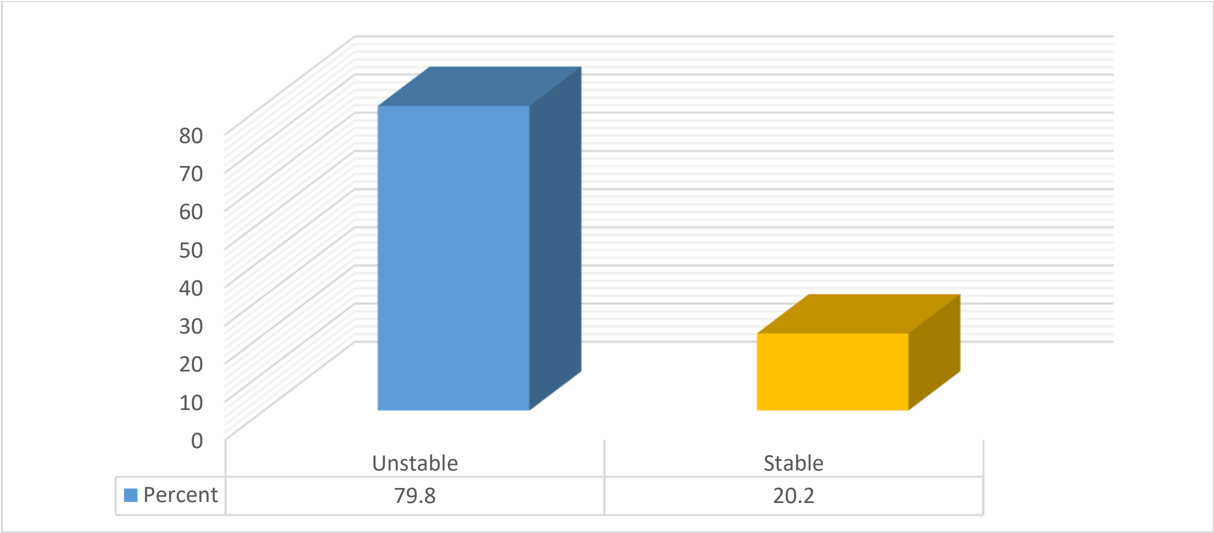
Figure 4 Percentage of dynamic balance



Spearman's correlation test was used to assess the effect of flexible flat foot on knee proprioception, static and dynamic stability (Table 2). The results showed a negative correlation between flexible flat foot and knee proprioception (r = -0.113, p 0.277) indicating that flexible flat foot does not a have direct effect on knee proprioception. Comparatively, a significant association was seen between flexible flat foot with both static (p = 0.031) and dynamic stability (p = 0.015) suggesting a direct effect of flexible flat foot on postural stability.

Variables		Knee	Static stability	Dynamic stability
Flexible flat foot	Correlation coefficient	-0.113	-0.223	-0.251
	P-value	0.277	0.031	0.015
	n	94	94	94

Table 2 Results of Spearman's rho test

(P<0.05: significant association between flexible flat feet and postural stability) (P>0.05: no significant association between flexible flat feet and knee proprioception)

The Spearman's correlation for the assessment of relationship between knee proprioception, static and dynamic stability indicated weak and statistically insignificant association between all the variables **(Table 3)**. For knee proprioception and static stability (p = 0.256). In terms of knee proprioception and dynamic stability (p = 0.384). Static and dynamic stability had a somewhat higher correlation at 0.163, but it was not statistically significant (p = 0.116). The outcomes demonstrated that in individuals with flexible flat foot, changes in knee proprioception do not substantially effect either static or dynamic stability.

Variables		Knee Proprioception	Static stability	Dynamic stability
Knee Proprioception	Correlation coefficient	-	0.118	0.091
	P-value	-	0.256	0.384
	n	-	94	94
Static stability	Correlation coefficient	0.118	-	0.163

	P-value	0.256	-	0.116
	n	94	-	94
Dynamic stability	Correlation coefficient	0.091	0.163	-
	P-value	0.384	0.116	-
	n	94	94	-

Table 3 Results of Spearman's rho test among the variables (P>0.05significant association among the variables

Discussion

The current study aimed to investigate the effect of flexible flat foot on knee proprioception and postural stability among physiotherapy students in Karachi. The results of this study revealed a significant prevalence of flexible flat foot (13.4%) among physiotherapy students in Karachi, which is consistent with previous researches that have reported varying prevalence ranging between 11.5% to 15.5%(3, 19). The majority of the participants revealed a high prevalence of bilateral flexible flat foot (92.5%), reinstating the notion that flat foot is often bilateral rather than unilateral(23).

The findings revealed a significant association between flexible flat foot and both static and dynamic stability with p value <0.05. This indicates that alterations in the foot biomechanics affects balance and postural stability in both static and dynamic states. The foot acts as the base of support in the kinematic chain with the supporting bone and soft tissues that help to maintain the structural stability of the lower limbs(6). Changes in the pattern of muscular activity of the foot mainly involving the posterior tibialis tendon and the dynamic stabilizers are believed to potentially affect the overall postural alignment in both static and dynamic activities(4). According to this, the results of this study aligned with the findings of recent studies(20, 32). The significant impairment in dynamic stability (79.8% of the participants) may increase the risk of fall particularly among young adults who tend to engage in more demanding physical activities(25). Whereas, static balance is required for maintaining balance during daily activities, therefore, any impairment in the postural stability requires the need for preventive strategies and interventions focusing on balance training to improve the functional independence among those individuals with flexible flat foot.

The results revealed that 97.2% of the individuals with flexible flat foot had a significantly reduced knee proprioception. The result of the study was consistent with previous studies(27, 34). Proprioception relays on somatosensory inputs from the sole of the foot to the central nervous system therefore alterations in the lower limb biomechanics can contribute to proprioceptive deficits eventually leading towards hindrance in maintaining balance and posture(32). However, the correlation analysis showed that there was no significance found between flexible flat foot and knee proprioception indicating no direct relationship among the two variables. The findings were therefore inconsistent with recent study suggesting a prominent relationship between the two variables(20). A reason for this dispute among the results may include the use of reconstruction of ankle and knee angle test as a measuring tool by Ghorbani in his study while in this research sharpened Romberg test in closed eye position was used for the assessment of knee proprioception. Therefore, the use of different measuring tools can be a cause of inconsistency between the two studies. While flexible flat foot may not severely impair knee proprioception, the compromised postural stability could affect the overall posture.

The findings also showed a non-significant correlation between knee proprioception, static and dynamic balance, which is consistent with the results of recent study(20). In individuals without flexible flat foot sensory or proprioceptive signals from sole of the foot provide enough information for maintaining balance and to understand situational fluctuations(6). This provides ability to predict balance and postural stability in both static and dynamic states. Whereas, in individuals with flexible flat foot impairment in sensory information is replaced by vestibular and visual input to help control the body alignment in a static or dynamic state(20). Since more attention load is on the vestibular and vision system there is improvement in postural stability while performing secondary task as focusing on a highly automatic process like balance can make it more effective. While some activities increase postural sway others tend to reduce postural sway. This improvement can be due to an increase in alertness and arousal that overall improves functional performance. Therefore, in individuals with flexible flat foot deformity knee proprioception scores are unable to predict or account for static and dynamic balance scores and vice versa.

Despite the significant results of the research certain limitations must be acknowledged. The cross sectional design of the study limits making conclusions regarding causal relationships between proprioception or postural stability and flexible flat feet. Also, the sample included 80.9% female and 19.1% male participants, reflecting an imbalanced ratio between the genders. In this study, we could not control the measures of weight, height, BMI and length of the lower limbs. These factors might have separate effects on results, contradicting the association between stability and flat foot that have been established. A control group with normal medial longitudinal arch was not included for comparison. Therefore, it is difficult to determine the impact of flexible flat foot on the findings in the absence of a comparison group, which makes it more difficult to limit the complications to flat foot alone. Furthermore, because of short time frames and the inability to obtain approval from certain physiotherapy institutes and universities, we were unable to reach our expected sample size of 545. In addition, a small sample size may lower the study's statistical power.

Conclusion

In summary, this research highlights the prevalence of flexible flat foot among physiotherapy students in Karachi and its significant implications for knee proprioception and postural stability. Although flexible flat foot does not seem to have a direct association with knee proprioception, It can significantly cause impairments in both static and dynamic stability. These findings require the need for appropriate rehabilitative approaches to enhance functional outcomes and improve quality of life for individuals with flexible flat foot.

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