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The therapeutic influence of short foot exercises on medial longitudinal arch and balance in a child with flat feet: A single case study

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Abstract
The Medial Longitudinal Arch (MLA) plays a very important role in shock absorption and helps in the proper functioning of the lower extremities during the gait cycle. Balance is a very crucial component for performing everyday activities. The development of flatfoot occurs when the MLA collapses leading to a balance deficit. The purpose of this study is to find out the effect of Short Foot Exercises (SFE) on increasing the height of MLA and improving balance in pediatric patients. In this study, we present a 3-year-old baby with balance issues due to flatfeet which was treated with SFE. In addition to being diagnosed with flatfeet, the baby also has a global developmental delay. She is receiving physiotherapy treatment six days per week.
This study assessed balance and foot function before and after the intervention using the Pediatric Balance Scale (PBS) and Navicular Drop Test (NDT). There was a significant improvement in the navicular drop test in both feet following the intervention. Additionally, the PBS score improved by 8 points after the intervention. This study concludes that SFE is beneficial in improving the MLA and overall balance in pediatric patients with flat feet.

Keywords: Balance dysfunction, children, medial longitudinal arch, short foot exercises

1. Introduction
The human feet play a very significant role in maintaining balance, posture, and cushioning despite occupying only 5% of the total body surface [1]. Their functions include gathering all the afferent information from the soles. The excessive relaxation of the medial longitudinal arch (MLA) can lead to flatfoot, which can impair balance and equilibrium. This excessive pronation of the foot causes the heel to evert and it compresses the MLA [2, 3]. The loss of balance can ultimately lead to difficulty in performing day-to-day activities, walking or running, resulting in reduced endurance [4, 5].
Flatfoot is found to be a prevalent condition within the pediatric population. It is considered normal for children to have flat feet, as the development of arches occurs over time in early childhood. However, flatfoot that persists beyond a certain age may cause concern. The prevalence of flexible flatfoot among children aged 3 to 6 years reveals intriguing age-related patterns. A study found that within this age range, the overall prevalence was 44%, indicating a substantial occurrence of this condition. The prevalence showed a distinct decrease with advancing age. Among 3-year-old children, a majority of 54% exhibited flat feet, highlighting its common occurrence in early childhood. However, as the children progressed to 6 years of age, the prevalence significantly dropped to 24%, suggesting a natural trend of resolution or development of arches as they grow older [6].
Several factors can interact to cause flat feet, and the prognosis depends on these factors as well as the underlying etiology, length of symptoms, and course of treatment. Treatment for flatfoot can be challenging, and symptoms may worsen with time due to conditions including Charcot arthropathy and inflammatory arthritis. A tense gastrocnemius muscle, problems with the achilles tendon, or tears in the posterior tibial tendon are some other causes of flat feet [7].
Rigid and flexible flat feet are the two types. Flexible flat feet that are clinically asymptomatic usually do not require intervention, but rigid cases often require surgery [8].

Conservative treatments, such as medication, diet, orthoses, physical therapy, and exercise are beneficial for symptomatic conditions. Extrinsic and intrinsic foot muscles are strengthened during exercise therapy, with an emphasis on the latter specifically in recent times. The flexor digitorum longus and other extrinsic muscles are mainly worked during toe bending and towel curl workouts. By way of engaging intrinsic foot muscles, SFE concentrates on sensory-motor training. Flatfoot conditions are improved by SFE, which actively encourages the development of both the longitudinal and transverse arches [9].

As the taller of the two longitudinal arches, the medial arch is made up of the first, second, and third metatarsals, as well as the calcaneus, talus, navicular, and three cuneiforms. Resting on the calcaneus and metatarsal heads, its highest point is located at the superior articular surface of the talus. With the plantar calcaneonavicular ligament providing support, the deltoid ligament offering medial reinforcement, and the tibialis posterior tendon providing inferior reinforcement, the talus-navicular joint is considered the weakest part of the arch, despite its well-known elasticity. Additional support is provided by the tibialis anterior and posterior tendons, the peroneus longus tendon, small foot muscles, ligaments across relevant articulations, and the plantar aponeurosis. Functioning as a spring that absorbs stress and adapts to uneven surfaces, the medial longitudinal arch is essential for balance. Its height and suppleness, supported by tendons and ligaments, aid in stability and the even distribution of weight [10].

The SFE strengthens intrinsic foot muscles by forming a medial longitudinal arch and drawing the first metatarsal head towards the heel without excessive toe movement. This exercise enhances balance, prevents navicular drop, and benefits both normal and flat feet by activating the abductor hallucis, which contributes to navicular and overall foot stability. Proper execution, without engaging extrinsic muscles like the tibialis anterior, is crucial for its effectiveness [9].

Toe bending and towel curl exercises primarily target extrinsic muscles like the flexor digitorum longus. In contrast, Short Foot Exercise (SFE) emphasizes sensory-motor training by activating intrinsic foot muscles to actively develop longitudinal and transverse arches. SFE adopts a targeted approach, focusing on the coordination of these intrinsic muscles to enhance arch support and alleviate flatfoot symptoms [4].

2. Case report

A 3-year-old child was brought to the pediatric outpatient department due to balance difficulties associated with flat feet. Upon examination, the patient showed difficulty in maintaining her balance while sitting and standing. Although she can ascend and descend stairs with supervision, she relies on her hands for support to stand and cannot sustain her balance for long. Her performance on the Pediatric Balance Scale (PBS) was 34/56, indicating significant issues with balance. The patient showed delays in achieving developmental milestones, with gross motor skills limited to stair climbing and fine motor skills to drawing circles. Language development is at an early stage, with the ability to speak a few words. Social interaction skills are undeveloped and the highest achieved skill is waving goodbye. Through physical examination, it was revealed that the baby has reduced arches in the feet, hypotonia, and diminished deep reflexes in both upper and lower limbs. Pronation of bilateral ankles was observed, and in gait analysis, during the stance phase, absence of heel strike, inability to maintain foot flat for prolonged periods, increased weight shift to the right during midstance, and external rotation of the leg was noted to clear the ground during heel off, while in the swing phase, hip and knee flexion were reduced.

2.1 Physiotherapy Management

The patient underwent daily 10-minute physiotherapy sessions on weekdays for a total of 4 weeks, attending 6 days per week.

Short-term goals were to strengthen intrinsic foot muscles, improve arch stability, and enhance proprioception to improve balance. Long-term goals aimed to improve the functional activities, achieve independence, and improve the patient's quality of life.

The SFE program involved an initial demonstration of the exercise techniques by the therapist along with verbal instructions. And then the patient is made to sit on a height-adjustable chair with hip, knee, and ankle joints flexed at 90 degrees. The patient is instructed to pull the first metatarsal bone towards the heel without curling the toes, maintaining for 15 seconds to form the MLA, and repeating the same 10 times. This exercise was executed in the following stages:-

- Patient performing the exercise individually on each foot while seated.
- Patient performing the exercise individually on each foot while standing.
- Patient performing the exercise simultaneously on both feet while standing.

2.2 Outcome measure

Outcome measures, Navicular drop test (NDT) and Paediatric Balance Scale were recorded for each participant at the first baseline assessment and upon completion of the treatment intervention i.e., 4th week.

The NDT is a valid and reliable measure for individuals with flatfoot (ICC values ranging from 0.914 to 0.945) [11]. The height of the medial longitudinal arch (MLA) was determined through NDTs. Each subject was told to sit in a chair with their knee bent to a 90-degree angle, align their knee and second toes so that the subtalar joint was placed in the neutral position, and then measure the distance from the ground to navicular tuberosity in non-weight bearing condition. With the participant standing on both feet, shoulder-width apart, the distance between the ground and the navicular tuberosity on each foot was measured. A 3x5 index card and a plastic ruler were used to measure the difference in the height of the navicular tuberosity between the non-weight-bearing (sitting position) and weight-bearing (standing position) positions [4]. According to Mary Rose Franjoine *et al*. (2003), the PBS has strong test-retest reliability [Intra-class correlation coefficient (ICC) =.998] and inter-rater reliability (ICC=.997). The scale comprises 14 items, each scored from 0 points (lowest function) to 4 points (highest function), with a maximum possible score of 56 points [12, 13].

Fig 1: Flatfeet in non-weight-bearing

Fig 2: Flatfeet in non-weight-bearing condition

Fig 3: Patient performing short foot exercise

3. Result and Discussion

The present study was to evaluate the therapeutic influence of Short Foot Exercises on medial longitudinal arch and balance in a child with flatfeet.

The collapse of the (MLA), either partially or completely, can affect the lower extremity kinematics during normal movement [1]. These alterations often lead to various disorders such as Achilles tendinitis, IT band syndrome, knee pain, and low back pain. Additionally, MLA collapse can cause balance dysfunction, resulting in stability issues during activities that need weight distribution and coordination [15].

SFE mainly focuses on strengthening the intrinsic foot muscles which are the primary local stabilizers of the foot [16]. This present study was supported by Ching Huang et. al (2022) who concluded that SFE is an essential tool for foot alignment in flatfoot patients [16].

In this present study application of SFE showed improved results in balance and increased the height of MLA. The MLA is formed by the first metatarsal bone, cuneiforms, navicular, talus, and calcaneus. It supports the entire body weight that is transferred from the tibia to the talus through interconnected soft tissues [17]. IFM is integral for sensory feedback due to stretch response for foot posture [9]. SFE activates IFM efficiently, which helps prevent excessive pronation of the foot by lifting the MLA. This activation improves dynamic alignment, balance, and control arch positioning. [4] The present study was supported by Eun-Kyung Kim *et al* (2016) who proved that SFE improves the MLA height and balance ability [4].

The height of MLA is evaluated using the Navicular drop test which is the difference in navicular height between the weight-bearing standing and non-weight-bearing sitting positions [18]. This was supported by Zuil-Escobar JC *et al* (2018) who suggested that NDT measurements are a reliable and valid tool for measuring the medial longitudinal arch [11].

Functional balance in children is the ability to maintain the center of mass for the base of support during any childhood activities. The pediatric balance scale is a 14-item evaluation scale used to assess the balance ability in children. This was supported by a study conducted by Franjoine MR, *et al* (2010) which proved that PBS is the most appropriate scale to assess balance for children aged 3-6 years and it has excellent reliability and validity [12].

Previous studies on the effect of SFE on flatfoot patients have been conducted in various ways and the effectiveness of this exercise has been demonstrated. However, the therapeutic influence of Short Foot Exercises on medial longitudinal arch and balance in a child with flatfeet has not been thoroughly studied. Based on the results of this study, the intervention was effective in pediatric patients with flat feet.

3.1 Tables

Table 1: Physiotherapy intervention for flatfeet

Intervention	Intensity	Frequency	Duration
Sitting, one foot (Each)	15 seconds Hold-Relax (10 repetitions)	6 days per week	24 sessions
Standing, one foot (Each)	15 seconds Hold-Relax (10 repetitions)	6 days per week	24 sessions
Standing, both feet	15 seconds Hold-Relax (10 repetitions)	6 days per week	24 sessions

Table 2: Outcome measure Pre and Post-intervention values

Outcome measure	Pre-intervention value	Post-intervention value
Navicular Drop Test	Left-10.2±1.3mm Right-10.4±1.2mm	Left-7.4±1.1mm Right-7.8±1.1mm
Paediatric Balance Scale	34/56	42/56

4. Conclusion

This study concludes that Short Foot Exercises have a significant role in improving medial longitudinal arch (MLA) and balance in pediatric patients with flat feet.

5. Acknowledgement

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