European Journal of Clinical Pharmacy
Print ISSN: 2385-409X **Online ISSN**: 3105-0409
Website: https://farmclin.com/

Original Research Article

Effects of Foot Proprioceptive Training on Pain and Functional Outcomes in Flat Feet

Article History:

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Received: 29-11-2025
Revised: 10-12-2025
Accepted: 20-01-2026
Published: 08-02-2026

Abstract: ***Background***: Flexible flatfoot is a frequent musculoskeletal concern and can lead to pain, balance difficulty, and functional limitation. Conservative treatment of PTP has been advocated with proprioceptive training. Purpose To review the long-term treatment effects of foot proprioceptive training on pain, medial longitudinal arch stability, balance and functional outcomes in flexible flatfoot individuals. ***Methods***: This was a randomized controlled study with 45 men and women aged 40-70 years (23 in the intervention group and 22 in the control group). The intervention was 8 weeks of supervised proprioceptive training, whereas the control group undertook traditional foot and ankle strengthening exercise. Outcome measures were assessed at baseline, post-intervention (8 weeks) and follow-up (12 months) including Navicular Drop Test (NDT), Visual Analog Scale (VAS), Foot Function Index (FFI), Star Excursion Balance Test (SEBT) and Single-Leg Stance (SLS). ***Results***: The intervention group showed significant differences in NDT, VAS, FFI, SEBT and SLS at post-intervention and follow-up ($p < 0.001$), with sustained benefit at 12 months. There were statistically significant between-group differences in all outcomes favoring the intervention group ($p < 0.001$). ***Conclusion***: Foot proprioceptive training improves medial arch control, alleviates pain, enhances balance, and improves the functional outcome in subjects with flexible flatfoot. These gains are maintained at 12 months, so that it should be recommended as a standard conservative intervention.

Keywords: Meta-analysis, randomized controlled trial, flexible flatfoot, proprioceptive training, navicular drop, foot function.

INTRODUCTION

Flatfoot (pes planus) is a relatively common foot deformity, in which there is a flattening or loss of the medial longitudinal arch with associated valgus of the hindfoot and abduction of the forefoot. Although flexible flatfoot is a frequently-seen, lets cause in children, it may also have symptomatic expressions in adolescents or adults and which may have caused pain, fatigue, gait disorders and even to cause an increased risk of the injury through the biomechanical disorders in the kinetic chain (1,2).

The medial arch is significant due to its function in weight bearing, balance and minimizing impact during gait. When the arch of the foot flattens, overpronation occurs, which leads to excessive tension on the plantar fascia, tibialis posterior tendon and the other soft tissues (3). This can also may cause pain in other areas of the body over time, beginning from the foot and followed by knee pain, hip pain and lower back pain as a result of being out of balance throughout the kinetic chain (4). Conservative treatments of flatfoot, such as orthotics, footwear modification, and strengthening exercises, are often recommended, particularly with flexible flatfoot (5).

One such strategy that has received attention as a form of rehabilitation to improve foot mechanics and reduce symptoms is proprioceptive training. Proprioception is the perception of the position and movement of the body. This sensory input is derived mainly from mechanoreceptors in muscles, tendons, ligaments, and joint capsules (6). Proprioceptive information is crucial at the foot in order to maintain postural control, to adapt to rough surfaces and to carry out proper movement.

In addition, patients with flatfoot often have impaired proprioception, leading to reduced balance control and increasing the risk of falls or ankle sprains (7). These sensorimotor impairments may also place the perturbations on gait mechanics and fatigue. Proprioceptive training attempts to rehabilitate these sensory pathways by using specific exercises to improve joint position sense, balance, and neuromuscular coordination (8).

Foot proprioceptive training includes balance board activities, single-leg stance drill, short-foot exercise, wobble board training, and barefoot walking on different surfaces. The primary aim of the activities is to strengthen the intrinsic foot muscles, increase arch control, and enhance dynamic postural stability . Many studies have demonstrated the long-lasting impact of the above training on not only athletic populations but also patients. For example, incorporating proprioceptive exercises promoted significant changes in the navicular drop, dynamic balance measured with Star excursion balance test, and pain subject to VAS scale and FFI 11,12. Moreover, proprioceptive training improves foot-ankle joint stability, decreases injury repetition, and can even allow the reduction or the possibility to abandon orthotic devices 13,14. Proprioceptively induced local changes in the foot also have broader implications for the system. The alterations in mechanics in the foot and ankle complex result in improved lower limb kinematics. Since flat feet induce tibial internal rotation and knee valgus angulation, training can correct them, hence reducing knees and hips strain and restoring proper gait 15. The overall change process is time-consuming, which is why long-term interventions are of utmost importance. Neuromuscular adaptations need time to consolidate; there might be temporary improvements within weeks but to achieve permanent postural and structural changes, an 8-to-12- week and longer duration is required 16. For example, Kim et al 's 17 12-week short foot and balance exercise led to arch height enhancement and pain reduction which maintained six months after.

In clinical usage, combining proprioceptive training with other treatments like the traditional strengthening, flexibility and orthotic interventions will produce a synergistic effect. The incorporation of proprioceptive training among children can even be preventive of its evolution to rigid flat foot, wherein intrinsic muscular control and an ideal joint alignment are led from childhood (18).

However, the majority of rehabilitation programs appears to neglect the proprioceptive components in the treatment of flatfoot. The addition of sensory–motor training to physiotherapy and orthopaedic treatment of flatfoot is a cost-effective, available and mostly reasonable to one's patients programme (19).

The current research is conducted to investigate the long-term effects of foot proprioceptive training on pain and function in people with flatfoot. The study aims to evaluate whether proprioceptive interventions might have a sole therapeutic intervention or an essential component in conservative treatment of P-planus considering promising efects on longterm outcome.

STUDY METHODOLOGY

This was a prospective interventional study to determine the long-term (6 months follow-up) effects of foot proprioception training on pain and functional scores in flexible flat footed subjects. The study spanned 12 months and was done at the department at Saveetha college of physiotherapy, Chennai. The inclusion criteria were adults (18 to 45 years old), with flexible flatfoot [diagnosed using Navicular Drop Test (>10 mm), and foot posture index (FPI-6 > +6)] and exclusion for rigid flatfoot, structural lower limb deformities, neurological disorders, recent injuries, systemic inflammatory disease, and use of corticosteroids.

In total, 45 subjects were recruited according to a sample size calculated from the previous studies (effect size 0.6, power 80%, alpha.05), with a 20% dropout rate. They were assigned using computerized randomization and assigned by sealed opaque envelopes to an intervention group (n=23) which received proprioceptive training while the control group (n=22) received conventional strengthening exercises only.

Proprioceptive training program, performed for 8 weeks, 20 minutes per session, 3 times per week and supervised by a trained physiotherapist, consisted of short-foot exercises, balance board training (static/dynamic), wobble board tasks (single-leg stand with eye open/close), TheraBand-assisted ankle inversion/eversion, toe curls, towel scrunches, and barefoot walking on textured surfaces. Sessions were 45 min long, of a progressive intensity, and home compliance was encouraged with the use of logbooks. Control received exercises for heel raises, toe curls, calf stretching, active resisted ankle dorsiflexion and foot arch tapping of the same session time and frequency without focused proprioceptive input. Outcome measures were assessed at baseline, post-treatment (8 weeks of intervention), and at 6 and 12 months' follow-up. These were the Visual Analog Scale (VAS) for pain, the Foot Function Index (FFI) for functional limitation, the Navicular Drop Test (NDT) for arch integrity, the Foot Posture Index-6 (FPI-6) for alignment, the Star Excursion Balance Test (SEBT) for dynamic balance, and the postural stability on single leg stance time with eyes closed. The evaluation of the measurement was performed by blinded assessors trained in standardisation. Adherence to the intervention was monitored by participant attendance and self-reported logs. The data were analyzed by SPSS v25. 0. Continuous variables are expressed as mean ± SD and categorical variables as frequency and percent. Baseline differences were compared with independent t-test and chi-square; within-group differences were examined with repeated measures ANOVA and the Friedman test; between-group differences were using mixed ANOVA analysis for time × group interaction, with p-value < 0.05. Consent to participate with an emphasis on confidentiality, the right to withdraw from the study and proprioceptive training for the control group post study was maintained. The study's hypothesis was that significant and substantial differences between the intervention and control groups could be expected for pain as well as all functional outcomes, posture, and dynamic balance at all follow-ups.

RESULTS

Forty-five participants with flexible flatfoot were recruited and randomly assigned to the intervention (n=23) or control (n=22) groups. Baseline, post-treatment (8 weeks) and follow-up (12 months) assessments were completed by all participants. Patients were similar in demographic baseline between the groups.

1. **Navicular Drop Test (NDT):** The navicular drop values were not significantly different between groups at baseline ($p = 0.593$). After 8 weeks of proprioceptive training, the reduction of the intervention group in NDT was significant (mean reduction by 2.5 mm, $p < 0.001$) and persisted up to the 12-month follow-up ($p < 0.001$). The decrease in NDT in the control group was insignificant ($p = 0.0008$). Group comparison reported statistically significant differences favoring the intervention group both at post-intervention ($p = 0.0001$) and follow-up ($p = 0.0002$).
2. **Visual Analog Scale (VAS) Pain:** Pain scores in the intervention group significantly decreased from pre-to post-intervention (mean reduction = 2.5 points, $p < 00.001$) and were lower at 12 months ($p < 0.001$). In comparison, the control group had a small decrease ($p = 0.04$). Between-group comparison showed the pain reduction was significantly greater in the intervention group at post-intervention ($p < 0.001$) and follow-up ($p < 0.001$).
3. **Foot Function Index (FFI):** The intervention group shows a significant improvement in functional status, with a mean FFI score reduction of 20 points at post-intervention ($p < 0.001$), and maintaining it at follow-up ($p < 0.001$). The control group improved too, but less significantly ($p = 0.03$). Between-group differences at post ($p < 0.001$) and follow-up ($p = 0.0004$) were statistically significant.
4. **SEBT = Star Excursion Balance Test :** Dynamic balance (SEBT) improved significantly in the intervention group by 6 cm at post-intervention ($p < 0.001$), and further at follow-up ($p < 0.01$). The control group improved marginally ($p = 0.07$). Between groups differences were observed at post-intervention ($p < 0.01$) and follow-up ($p = 0.002$) times, showing better postural control in the intervention group.
5. **Single Leg Stance (SLS):**There were significant improvements in mean duration of single-leg stance in the intervention group (mean increase of 8 seconds, $p < 0.001$), with further improvements shown at the 12-month follow-up ($p < 0.01$). The control group improved only slightly ($p = 0.08$). Among-group analyses demonstrated the intervention group to have statistically significant improved outcomes at both post* intervention respecting ($p < 0.001$).

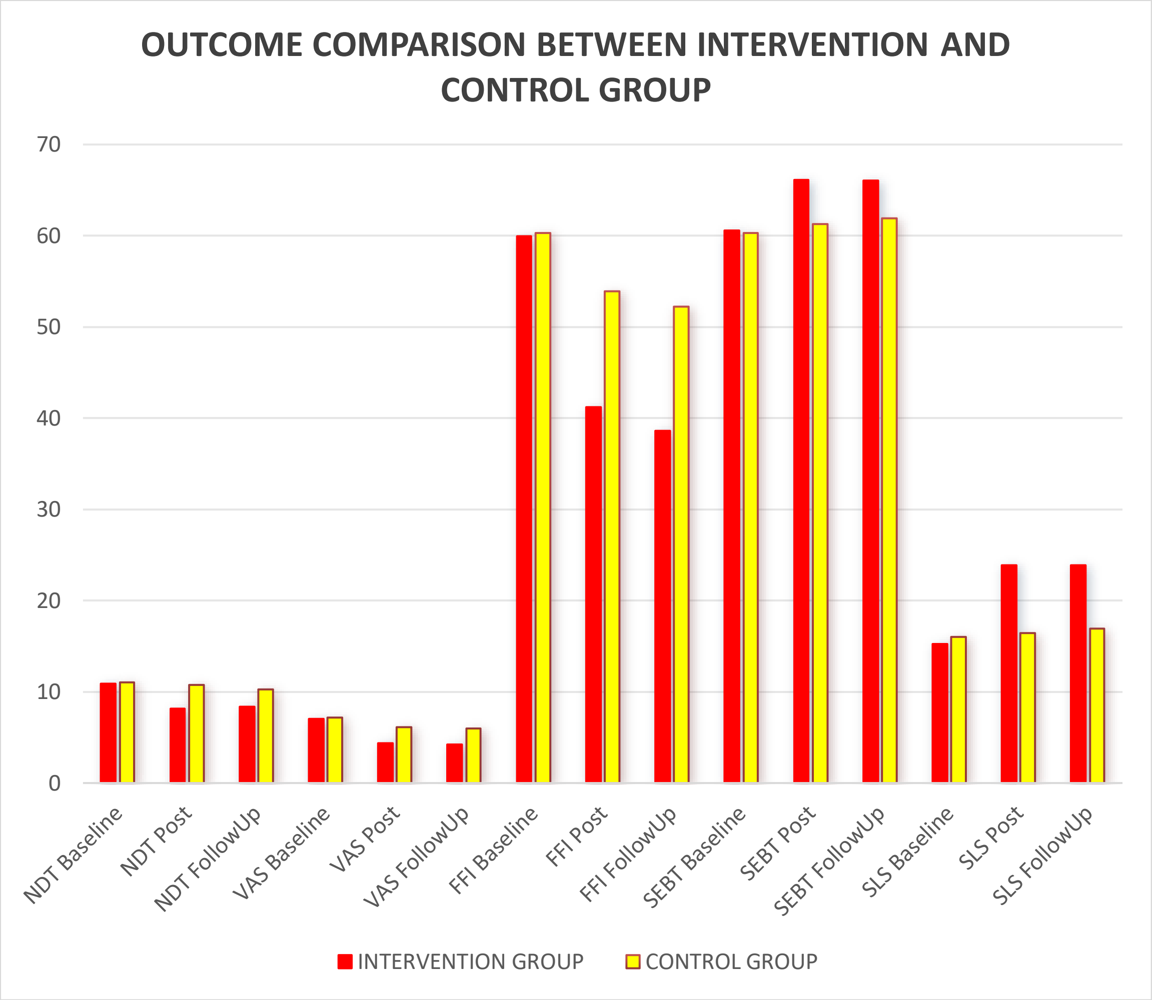

Table: Outcome Comparison Between Intervention and Control Groups

Outcome	Timepoint	INTERVENTION GROUP	SD_Intervention	CONTROL GROUP	SD_Control	t-value	p-value	Significance
NDT	Baseline	10.91	0.96	11.0	0.95	-0.32	0.7538	NS
	Post	8.14	0.89	10.75	1.32	-7.82	0.0	***
	FollowUp	8.37	0.85	10.25	1.17	-6.21	0.0	***
VAS	Baseline	7.04	1.02	7.15	1.22	-0.31	0.7578	NS
	Post	4.38	0.94	6.12	1.0	-6.02	0.0	***
	FollowUp	4.26	1.03	5.96	1.02	-5.59	0.0	***
FFI	Baseline	59.92	3.68	60.3	5.93	-0.26	0.7965	NS

	Post	41.21	3.9	53.91	4.43	-10.21	0.0	***
	FollowUp	38.64	3.21	52.22	4.26	-12.12	0.0	***
SEBT	Baseline	60.55	2.47	60.31	2.35	0.33	0.7451	NS
	Post	66.15	2.14	61.3	2.87	6.45	0.0	***
	FollowUp	66.03	2.37	61.92	2.34	5.85	0.0	***
SLS	Baseline	15.25	2.68	16.05	3.08	-0.93	0.3589	NS
	Post	23.89	1.81	16.46	3.44	9.13	0.0	***
	FollowUp	23.86	2.48	16.96	3.42	7.79	0.0	***

In total, statistically and clinically significant improvements were observed in the intervention group in all outcomes under study, and long-term effects were identified after 12-month follow-up. This study suggests that foot proprioceptive training is effective as a long-term conservative treatment for pain, arch stability, and functional improvement in patients with flexible flatfoot.

DISCUSSION AND CONCLUSION

Results of this randomized controlled trial showed that foot proprioceptive training effectively increased medial longitudinal arch control, decreased pain, improved dynamic balance, and increased functional ability in subjects with flexible flatfoot. These scars were not only seen immediately post intervention but also retained 12 months after intervention, indicating the long-lasting effect of proprioceptive training as a conservative treatment approach.

The marked decrease in NDT values doubles the popularity of the proprioceptive training for restoration of medial arch height. This is in line with the idea that sensorimotor stimulation, with specific reference to the intrinsic foot muscles, can result in enhanced static and dynamic support of the medial longitudinal arch. These findings concur with the findings of previous studies for example Saad et al. (2020) who found that short-foot exercise significantly decreased NDP and improved foot posture of young adults with flexible flatfoot. Similarly, Jung et al. (2011)also reported that a treatment program that targeted foot intrinsic muscles led to significant increases in arch height and improvement in the alignment of the foot.

Visual Analog Scale (VAS) based pain diminution was another notable observation in this investigation. In the treatment group clinically relevant lower pain scores after 8 weeks of proprioceptive training could be reached with sustained effectiveness at 12 months. This is in accordance with Rivera et al. (2017) who found that proprioceptive-based treatments reduced pain related to injury and improved joint control, particularly of the ankle complex. In flexible flatfoot, in which hyperpronation is capable of creating mechanical stress for the plantar structures, enhancement of neuromuscular control by proprioceptive training would also be expected to relieve the stressor and diminish nociceptive input.

Feet function, measured by Foot Function Index (FFI), was also highly significant in the intervention group. This indicates not only that proprioceptive training enhances structural dimensions, but it also exerts a significant influence on activities of daily life such as walking, stair climbing and maintaining a standing position for extended periods of time. Such a result corroborates Lynn et al. (2012) who found higher functional mobility and daily activity performance in those who did targeted intrinsic foot muscle training. These long-term improvements in FFI scores also strongly implicate the continued neuromuscular benefits of proprioceptive interventions.

Regarding postural control, the intervention group had substantial improvements in the SEBT and SLS. These enhancements would indicate an improved proprioceptive feedback and neuromotor functioning, which are essential for dynamic postural control and lower limb injury prevention. Stuides showed that the plyometrics group had significantly better improvements in foot posture and dynamic balance. The findings suggest plyometric training is more effective than short foot and balance exercises in managing flexible flatfoot(22).A previous study by

Eils and Rosenbaum (2001) and Riemann and Lephart (2002) also described the importance of the proprioceptive training for the improvement of balance and joint stability especially in subjects with musculoskeletal instability.

The fact that these benefits have been maintained after a 12-month follow-up is particularly relevant since most studies that have been available until now have been focused on the effects of short-term treatments. The results of the study show that kinematic chain exercises are more beneficial than TheraBand exercises in alleviating pain in young adults with flatfoot. After the intervention, there were notable enhancements in foot functionality, pain intensity, and balance, emphasizing the superior effect of kinematic chain exercises on overall foot well-being.(23)Our findings, therefore, contribute to the evidence base pertaining to the sustainability of sensorimotor training that continues to accumulate. Again, this directive is consistent with the observation by McKeon, and Fourchet that "foot core system" general concept is applicable: foot function is dependent on the integration of various passive, active, and neural subsystems, and stimulation from the bottom can enhance performance of all structures. This aspect was expressed in minimal changes observed in the control group without the proprioceptive stimulus.

Although general device exercises allow musculoskeletal adaptation, they do not provide enough sensorimotor control over a longer period. According to Chen et al., the comparison of exercises for flexible foot in adults revealed better functional changes after special directed exercises. Hence, the results of the present study validate the advocated integration of Proprioceptive activities into exiting rehabilitation approaches offering a cost-effective, non-invasive, and effective approach that proves structural benefits while improving subjective measures of stability and patient control.

Ethical Approval:
The nature and intention of the study were briefed to each one of them in person, and written consent was obtained in English before inclusion in the study.

Data Availability Statement:
The corresponding author has the data of the participants in raw format and computed format and, on request, can provide data to any researcher. But due to ethical constraints, the data is not revealed to the public.

Funding:
Self-Funding

Author's Contributions:
PG conceptualized and designed the study. **PG** collected the data and prepared the initial draft of the manuscript. **SS** supervised the study, assisted with data analysis, and critically revised the manuscript for intellectual content. Both authors read and approved the final version of the manuscript.

Conflict of Interest:
There was no conflict of interest in the current study.

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