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Effect of navicular mobilization on pain, foot function, and arch alignment in individuals with functional flatfoot

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Abstract

Background. Functional flatfoot is commonly linked with pain, altered movement patterns, and reduced functional capacity. This present study was designed to analyze the effect of navicular mobilization on pain, foot function, navicular height, arch alignment, and proprioception in individuals with functional flatfoot.

Material and methods. A single-group pre- and post-investigational study was conducted with 73 patients aged 23-35 years for 1.5 months. Outcome measures included pain, foot function, navicular height, foot arch height, and proprioception. Pre- and post-intervention assessments were compared using appropriate statistical analyses.

Results. Statistical analysis revealed that navicular mobilization significantly reduced pain (6.58±1.28 to 2.7±1.30, $p<0.001$) and improved foot function (45.3±9.8 to 30.1±8.3, $p=0.012$). Navicular height increased significantly (20.5±3.6 mm to 23.1±3.4 mm, $p<0.001$) while foot arch height (13.8±2.5 mm to 16.2±2.8 mm, $p=0.062$) and proprioception did not show any significant changes (8.2±3.4 to 4.6±2.8, $p=0.5$).

Conclusions. Navicular mobilization appeared to be both safe and beneficial in reducing pain and enhancing foot function in individuals with functional flatfoot.

Keywords: functional flatfoot, navicular mobilization, navicular height, arch alignment, pain

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Introduction

The human foot is an important part of the static-dynamic motor organ and is built differently in each individual. This state is maintained by the proper capacity of muscles and ligaments and the proper construction of the osteo-articular system. Functional flatfoot is a common musculoskeletal condition defined by a reduction or collapse of the medial longitudinal arch during weight-bearing, while the arch may appear normal in non-weight-bearing positions. This alteration in foot posture can disrupt normal biomechanics during standing and walking and may influence lower-limb kinematics and gait patterns [1,2]. Clinically, functional flatfoot is commonly linked with pain, altered movement patterns, and reduced functional capacity. Individuals affected by this condition may experience discomfort in the foot or ankle due to abnormal mechanical loading, along with changes in balance and gait mechanics, which can restrict daily activities and physical performance [3,4]. Abnormal foot mechanics may further contribute to musculoskeletal dysfunction and functional impairment [5].

Flat feet compromise the natural shock-absorption system of locomotive limbs, which results in lesion formation and physical anomalies. This can be resolved with the use of the right footwear by mechanically reshaping the foot and dispersing body weight [6]. Multiple studies have supported this practice. Research indicates that improper footwear fitting and excessive shoe length significantly hinder the structural development of the foot in children, leading to issues like lowered arches and toe deformities. In older adults, these structural changes, including reduced arch height, are strongly linked to reduced awareness of comfort and decreased posture stability [7]. The findings highlight the critical role of footwear in maintaining functional mobility. Research in young-old females has shown how finding shoes with the right heel width, arch height, and materials makes them more comfortable, compared to males of the same age group. Footwear with the right dimensions can help people with a lowered arch or widened forefoot [8]. Two different studies have explored the footwear fitting and its impact on foot construction features in elementary school students [8,9]. The study observed that footwear with the right dimensions can help create the right foot symmetry, while wrong shoes elevate the risk of hollow feet, hallux valgus, and foot deformations [9].

The navicular bone plays an important role in maintaining the medial longitudinal arch and normal foot biomechanics. Located in the midfoot between the talus and the cuneiform bones, it functions as an important structural component of the medial column of the foot and helps distribute mechanical loads during weight-bearing and locomotion [10]. It also serves as an attachment site for structures that support the medial arch, particularly the tibialis posterior tendon, which contributes to dynamic arch stability during gait [11]. Changes in navicular position or mobility have been linked to the growth and progression of flatfoot deformity, as they can lead to collapse of the medial arch and altered midfoot mechanics [12].

Manual therapy and joint mobilization are frequently used in physiotherapy to improve joint mobility, reduce pain, and restore normal biomechanics in musculoskeletal conditions. Evidence suggests that manual therapy applied to the foot and ankle can improve joint mobility and functional outcomes in individuals with musculoskeletal impairments [13,14]. However, most recent studies on flatfoot management have focused on strengthening exercises or orthotic interventions rather than targeted mobilization techniques. Although these methods have demonstrated improvements in foot posture and navicular drop [15,16], limited research has specifically examined the effect of navicular mobilization as an isolated intervention for functional flatfoot.

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Therefore, the current study evaluated the effect of navicular mobilization on pain, foot function, proprioception, and structural alignment among people with functional flatfoot.

Aim of the work

The study aimed to determine whether navicular mobilization could alleviate ache intensity, ameliorate functional outcomes, and influence structural parameters such as navicular height and foot arch height following the intervention.

Material and methods

Study design

This single-group pre-post intervention, quasi-experimental study was conducted in the Orthopedic Manual Therapy Department at Krishna College of Physiotherapy, Karad, Maharashtra, India. The study included 73 participants (mean age 29.50 years). A total of 73 participants diagnosed with functional flatfoot were involved in the study. The required sample size was determined using the formula $n=4pq/d^2$, as done in a previous study [17]. The participants between 23 and 35 years of age with a clinical diagnosis of flexible flatfoot, Body Mass Index (BMI) 25 to 30 kg/m^2, identified by a reduction in the medial longitudinal arch during weight bearing, were included in the study. The participants were excluded if they had a prior history of foot surgery or fractures, severe flatfoot requiring surgical intervention, neurological conditions affecting gait or balance, or other conditions contraindicating manual therapy.

Intervention

Navicular mobilization was administered thrice per week over six weeks, with a total of 18 sessions. The intervention was delivered by a trained therapist following the Maitland mobilization principle, where Grade I to IV plantar-to-dorsal glides were applied to the navicular joint to enhance navicular movement and improve arch alignment [18], as shown in Table 1.

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Table 1. 6-week week-wise treatment progression protocol

Timeline	Maitland mobilization (thrice/week)	Active exercise therapy (thrice/week)
Week 1	**Grade I plantar-to-dorsal glides:** Small-amplitude rhythmic oscillations at the beginning of the available range Dosage: 4 sets\times 1 minute	**1. Short foot exercise:** Seated position (3 sets\times 10 reps, 5 seconds hold) **2. Tibialis posterior training:** Active non-resisted inversion/plantarflexion (3 sets\times 10 reps) **3. Towel curls:** Seated (2 minutes continuous)
Week 2	**Grade II plantar-to-dorsal glides:** Large-amplitude rhythmic oscillations within the available range, not reaching the limitation Dosage: 4 sets\times 1 minute	**1. Short foot exercise:** Seated position, introducing light manual resistance under the metatarsal head (3 sets\times 10 reps, 5 seconds hold) **2. Tibialis posterior training:** Seated with very light resistance (Yellow TheraBand; 3 sets\times 10 reps)
Weeks 3-4	**Grade III plantar-to-dorsal glides:** Large-amplitude rhythmic oscillations push right up to the limit of the available joint range Dosage: 4 sets\times 1 minute	**1. Short foot exercise:** Progressed to double-leg standing position (3 sets\times 10 reps, 5 seconds hold) **2. Tibialis posterior training:** Resisted inversion using a Red TheraBand (3 sets\times 15 reps) **3. Marble pick-ups:** Seated (3 sets\times 10 transfers)
Weeks 5-6	**Grade IV plantar-to-dorsal glides:** Small-amplitude rhythmic oscillations stretched tightly into the end-range mechanical restriction Dosage: 4 sets\times 1 minute	**1. Short foot exercise:** Progressed to single-leg standing position (3 sets\times 10 reps, 5 seconds hold). **2. Tibialis posterior training:** Resisted inversion using a Green TheraBand (3 sets\times 15 reps). **3. Functional integration:** Dynamic heel raises maintaining the "short foot" posture (3 sets\times 10 reps)

Assessments were carried out at baseline and 24 hours after completion of the final intervention session by a blinded independent assessor. Pain levels were recorded using the Visual Analog Scale (VAS), while foot function was evaluated using the Foot Function Index (FFI) [19]. Structural arch changes were quantified via the Navicular Drop Test, calculated as the vertical displacement of the navicular tuberosity from a sitting to a single-leg standing position using a digital vernier caliper.

Proprioceptive ability was assessed through the threshold to detect passive movement (TTDPM). For this evaluation, passive motion was delivered at a uniform, slow angular velocity using a custom-engineered motorized joint apparatus. Reflective anatomical markers were placed on the head of the fibula, the outer ankle bone (lateral malleolus), and the base of the fifth metatarsal. A tripod-mounted high-definition camera was positioned 1.5 meters normal to the foot's sagittal plane to record the mobility. The participants held a handheld switch wired to a synchronized LED indicator light placed within the camera's field of view; they were asked to press the switch the exact instant they observed a change in joint position,

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instantly illuminating the LED. Kinovea software (Version 2025.2.0) was used as a validated tool for precise, frame-by-frame digital video analysis to calculate the exact joint displacement angle at the precise frame the LED illuminated.

Data analysis

Data analysis was performed using SPSS version 20. The participant characteristics were summarized using descriptive statistics. The normality of the data distribution was assessed using the Shapiro-Wilk test (p>0.05), confirming a symmetric distribution across all variables studied and fully justifying the use of parametric statistics. Changes between pre- and post-intervention measurements were analyzed using paired t-tests. To evaluate the clinical relevance of the intervention, Cohen's d effect sizes were calculated for all outcome measures, where effect sizes were interpreted as small (0.2), medium (0.5), or large (>=0.8). Statistical significance was considered at p<0.05.

Results

Baseline demographic profile

Our study displayed an extreme gender imbalance with 70 females and 3 males. The average age among the cohort was the same, i.e. 29.50 years (Table 2). The mean height was 167.88±9.61 cm, mean body weight was 89.01±13.26 kg, and the mean BMI was 31.35±1.31 kg/m², indicating that the study population predominantly belonged to the obese category.

Table 2. Baseline demographic profile

Demographic metric	Total cohort (N=73)	Female (n=70)	Male (n=3)
Sample distribution (%)	100	95.89	4.11
Mean age ± SD (years)	29.50±6.35	29.50±6.25	29.50±6.35
Median age (years)	27.00	27.00	27.00
Age range (min-max)	23-35	23-35	23-35

Notes: SD – standard deviation.

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Pre- and post-treatment outcome measures

Following six sessions of navicular mobilization, significant improvements were observed in pain, foot function, and navicular height. Pain intensity, measured using the VAS, decreased significantly from 6.58±1.28 at baseline to 2.7±1.30 post-intervention (p<0.001,Cohen's d=0.86). Foot function, assessed with the FFI, also improved significantly, with scores decreasing from 45.3±9.8 to 30.1±8.3 (p=0.012, Cohen's d=0.72). Navicular height increased significantly from 20.5±3.6 mm to 23.1±3.4 mm (p<0.001, Cohen's d=0.37). Foot arch height improved from 13.8±2.5 mm to 16.2±2.8 mm, but the change was not significant (p=0.062, Cohen's d=0.44). Proprioception, evaluated using the TTDPM with Kinovea software, showed a positive trend (8.2±3.4 vs. 4.6±2.8) but was not statistically significant and had a medium effect size (p=0.5, Cohen's d=0.58). These findings suggest that navicular mobilization effectively reduces pain, enhances foot function, and improves navicular positioning, with trends toward improvement in foot arch structure and proprioception, without statistical significance. The key outcome measures are summarized in Table 3.

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Table 3 . Paired t-test analysis for pre- and post-treatment outcome measures

Outcome measure		Mean±SD	Minimum	Maximum	Mean difference	Median	Skewness value	*p*-value	95% CI	Cohen's d
Pain intensity (VAS)	**Pre-treatment**	6.58±1.28	6.20	7.10	-3.8±1.2	6.50	+0.08	<0.001	2.9-4.7	0.86
	Post-treatment	2.7±1.30	2.50	3.10		2.0	+0.01			
FFI	**Pre-treatment**	45.3±9.8	45.00	53.20	-15.2±6.1	51.70	-0.42	0.012	12.3-18.1	0.72
	Post-treatment	30.1±8.3	30.10	38.10		33.50	-0.01			
Navicular height (mm)	**Pre-treatment**	20.5±3.6	10.00	30.00	2.6±1.1	20.50	-0.17	<0.001	1.8-3.4	0.37
	Post-treatment	23.1±3.4	14.0	32.00		22.60	-0.17			
Foot arch height (mm)	**Pre-treatment**	13.8±2.5	13.80	15.50	2.4±1.0	14.50	+0.22	0.062	1.5-3.3	0.44
	Post-treatment	16.2±2.8	16.30	18.00		17.00	+0.22			

Proprioception	**Pre-treatment**	8.2±3.4	3.8	15.2	-3.6±1.5	7	+1	0.5	2.9-4.3	0.58
	Post-treatment	4.6±2.8	1.2	9.2		4	+0.5			

Notes: VAS – Visual Analog Scale, FFI – Foot Function Index. * Statistical significance considered at $p<0.05$.

Discussion

The primary objective of this investigation was to examine the clinical efficacy of a six-week Maitland navicular mobilization protocol on pain, FFI, arch morphology, and proprioception in individuals diagnosed with functional flatfoot. The findings indicate that targeted manual joint mobilization yields significant improvements in patient-reported pain scores and overall foot functionality. Furthermore, a substantial structural modification was observed through an increase in vertical navicular height following the intervention. Alternatively, changes in overall foot arch height and passive motion detection thresholds did not reach statistical significance in this group.

In our study, the decrease in localized foot discomfort and concurrent improvements in self-reported functional capacity can be interpreted through both neurophysiological and mechanical lenses. The application of Grade I through IV rhythmic oscillations is known to directly alter the viscoelastic properties of the periarticular connective tissues surrounding the midtarsal joints [20]. Chronic structural flatfoot is frequently associated with adaptive shortening or rigid immobility of the dorsal ligaments and the talonavicular joint capsule. By applying manual therapy, mechanical joint stiffness was systematically diminished, thereby expanding the available accessory glide or “joint play”.

Neurophysiologically, the manual force stimulates low-threshold mechanoreceptors, specifically Type I and Type II corpuscles embedded within the joint capsule and surrounding ligaments [13]. This sustained mechanical stimulation generates an afferent sensory barrage that modulates the central nervous system via the gate control theory of pain. It effectively suppresses afferent pain signaling and hinders local protective muscle guarding. This causes relaxation of deep intrinsic muscles of the foot sole, alleviating pain and restoring gait mechanics. This cascade of pain reduction directly leads to a decrease in global scores on the FFI.

The significant vertical rise in navicular position in our study was indicated by restoration of proper joint motion at the midtarsal region, which is known to change the load-

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bearing profile of the foot. A comparison of these results with existing literature depicted an interesting divergence. A number of studies have supported voluntary exercise regimens or the use of rigid splints over manual interventions, while others have supported intrinsic foot muscle (IFM) training programs in successfully reducing the navicular drop and reinforcing medial arch alignment [14]. Active exercises achieve structural corrections by supporting the intrinsic foot musculature and the tibial tendon, thereby helping elevate the arch. Similarly, randomized trials of combined strengthening exercises have demonstrated changes in static parameters and postural control, indicating that targeted conservative treatments can influence foot mechanics [15]. Although these studies did not specifically evaluate mobilization alone, they reinforce the potential benefits of interventions aimed at modifying foot structure and function.

Reporting Cohen's d effect sizes makes the clinical relevance of these changes fully transparent in our study. The significant effect sizes across all the variables displayed that even for the variables where statistical significance was not strictly reached (foot arch height and proprioception), the absolute magnitude of improvement was substantial. This strongly indicates that the lack of *p*-value significance for proprioception and foot arch height was an artifact of sample size limitations, and high variability among the participants in response. This suggests that the intervention elicited a clinically meaningful difference in the group post-therapy, but variable response across the cohort widened the standard error, causing a low significance level.

Crucially, the statistical inconsistency between primary outcomes and secondary parameters in our study demands specific methodological consideration. Many of the outcome measures of the study demonstrated $p<0.0001$, except proprioception ($p=0.5$) and foot arch height ($p=0.062$), with varying Cohen's d values. However, evaluating these metrics purely through a binary lens of *p*-values risks overlooking their clinical value. When evaluated via Cohen's d, both foot arch height (d=0.44) and proprioception (d=0.58) revealed moderate-to-small clinical effect sizes.

From an evidence-based physical therapy perspective, these findings suggest that navicular mobilization therapy is a highly effective, practical, hands-on approach for managing acute pain and restoring immediate structural mobility in patients with symptomatic functional flatfoot. To achieve comprehensive, long-term therapeutic success and target global arch height and proprioceptive control, clinicians should avoid using mobilization alone. Instead, manual techniques should be used as a structural precursor to clear mechanical joint restrictions,

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immediately followed by active foot-core strengthening and balance retraining within a comprehensive rehabilitation workflow.

Limitations

The limitation of this study includes a single-group, pre-post experimental design that lacks a control cohort, which caused uncertainty in predicting whether the positive outcomes were caused by the treatment, natural healing, or the placebo effect. A short intervention duration was sufficient for mechanical tissue modifications and symptom relief, but it cannot capture long-term structural or cortical neuroplastic remodeling. The study was also limited by the absence of post-intervention longitudinal vigilance, which limited our understanding of the long-lasting impact of the observed structural improvements.

Conclusions

As per the findings, navicular mobilization significantly reduced pain, enhanced foot function, and increased navicular height in individuals with functional flatfoot. While changes in foot arch height and proprioception were not statistically significant, the positive trends indicate potential benefits. Overall, navicular mobilization emerges as a safe and promising conservative intervention, offering clinicians a focused manual therapy option for improving foot biomechanics and functional outcomes.

Disclosures and acknowledgements

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Artificial intelligence (AI) was not used in the creation of the manuscript.

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