Journal of Exercise Science & Physiotherapy Volume 22 No.1 (January - June) 2026
I2OR Impact Factor = 7.860 ISSN: 0973-2020 (Print) ISSN: 2454-6089 (Online)

JOURNAL OF
EXERCISE SCIENCE
AND PHYSIOTHERAPY
Indexed, Peer Reviewed, Referred
Since 2005

Effectiveness of Gluteal Muscle Strengthening with Talonavicular Mobilization Versus Short Foot Exercise with Talonavicular Mobilization as a Precautionary Strategy for Medial Longitudinal Arch Integrity in Young Adults

Periyasamy Angamuthu, Mohammed Amal, Asha Shanthi and Jayabharathi

Abstract

Background: Flexible flat foot is a common musculoskeletal condition characterized by collapse of the medial longitudinal arch during weight-bearing activities. Weakness of intrinsic foot muscles and proximal hip stabilizers, particularly the gluteal musculature, has been identified as an important contributing factor in the development and persistence of flexible flat foot. Talonavicular mobilization has gained attention as a therapeutic intervention for restoring midfoot mobility and improving foot biomechanics. However, limited evidence exists comparing the effectiveness of proximal strengthening and intrinsic foot muscle strengthening when combined with talonavicular mobilization. Therefore, this study aimed to compare the effectiveness of gluteal muscle strengthening with talonavicular mobilization versus short foot exercise with talonavicular mobilization as a precautionary strategy for maintaining medial longitudinal arch integrity in young adults with flexible flat foot. **Results:** Twenty participants diagnosed with flexible flat foot and aged between 18 and 25 years were randomly allocated into two intervention groups. Group A received gluteal muscle strengthening exercises combined with talonavicular mobilization, whereas Group B received short foot exercises combined with talonavicular mobilization. Both groups underwent treatment five sessions per week for four consecutive weeks. Navicular Drop Test measurements were recorded before and after intervention. Statistical analysis revealed significant improvements within both groups ($p < 0.001$). Group A demonstrated a greater reduction in navicular drop values compared to Group B. Between-group analysis of post-test scores revealed a statistically significant difference favouring Group A ($t = 6.9416$, $p < 0.001$). **Conclusions:** Both intervention programs were effective in improving medial longitudinal arch integrity among young adults with flexible flat foot. However, gluteal muscle strengthening combined with talonavicular mobilization was significantly more effective than short foot exercise combined with talonavicular mobilization. The findings support the incorporation of proximal hip strengthening as a preventive physiotherapy strategy for improving foot posture and reducing the risk of future biomechanical complications associated with flexible flat foot.

Periyasamy Angamuthu
Department of Physiotherapy, Sree Abirami College of Physiotherapy, Coimbatore, Tamil Nadu, India
Email: periyasamyphysio@abiramiedu.in
Mohammed Amal
Department of Physiotherapy, Sree Abirami College of Physiotherapy, Coimbatore, Tamil Nadu, India
Asha Shanthi
Department of Physiotherapy, Sree Abirami College of Physiotherapy, Coimbatore, Tamil Nadu, India
Jayabharathi
Department of Physiotherapy, Sree Abirami College of Physiotherapy, Coimbatore, Tamil Nadu, India

Key words: Flexible flat foot; Medial longitudinal arch; Navicular drop test; Gluteal strengthening; Short foot exercise; Talonavicular mobilization; Preventive physiotherapy

DOI: 10.18376/jesp/2026/v22/i1/47764

Introduction

Flexible flat foot, commonly referred to as pes planus, is a musculoskeletal condition characterized by partial or complete collapse of the medial longitudinal arch (MLA) during weight-bearing activities. The MLA plays a crucial role in shock absorption, load distribution, maintenance of balance, and efficient locomotion. Alterations in arch structure may adversely affect lower-limb biomechanics and predispose individuals to a variety of musculoskeletal disorders (Williams and McClay, 2000; Banwell et al., 2018). Flexible flat foot is one of the most frequently observed postural abnormalities among adolescents and young adults. Although many individuals remain asymptomatic, persistent collapse of the MLA may result in excessive foot pronation, altered gait mechanics, muscular fatigue during prolonged standing, reduced functional performance, and an increased risk of injury throughout the kinetic chain (Franco, 1987; Murley et al., 2009). Excessive pronation has been associated with several lower-extremity conditions, including plantar fasciitis, patellofemoral pain syndrome, Achilles tendinopathy, medial tibial stress syndrome, and low back pain (Powers, 2003; McPoil and Cornwall, 1996). The stability of the MLA is maintained through the coordinated interaction of passive and active supporting structures. Passive stabilizers include the plantar fascia, spring ligament, joint capsules, and osseous architecture of the foot, whereas active support is provided by intrinsic and extrinsic foot musculature. The tibialis posterior, tibialis anterior, flexor hallucis longus, and peroneal muscles contribute significantly to dynamic arch stabilization during functional activities (Neumann, 2017; Donatelli, 1996). Weakness or dysfunction of these structures may contribute to progressive arch collapse and altered lower-extremity alignment.

Recent evidence has emphasized the importance of proximal muscle control in maintaining optimal foot posture and lower-limb biomechanics. The concept of regional interdependence suggests that impairments in proximal segments may influence distal structures through the kinetic chain. In particular, the gluteus maximus and gluteus medius serve as primary stabilizers of the pelvis and lower extremity during weight-bearing activities. Weakness of these muscles may increase femoral internal rotation and adduction, resulting in compensatory tibial internal rotation and excessive foot pronation (Powers, 2003; Kendall et al., 2005). Consequently, strengthening the gluteal musculature may positively influence foot biomechanics and contribute to restoration of MLA integrity. Gluteal strengthening exercises such as clam shells, side-lying hip abduction, prone hip extension, and bridging exercises are commonly prescribed in physiotherapy practice to improve proximal stability and lower-limb alignment. Previous studies have demonstrated that strengthening the gluteus maximus and associated stabilizing musculature can reduce navicular drop and improve lower-extremity muscle activation patterns in individuals with flexible flat foot (Goo et al., 2016). These findings support the hypothesis that proximal interventions may have beneficial effects on distal foot posture. Short foot exercise is another widely used intervention aimed at enhancing the function of intrinsic foot muscles responsible for maintaining arch support. The exercise involves drawing the metatarsal heads toward the heel without flexing the toes, thereby activating the intrinsic musculature and improving dynamic foot stability. Several investigators have reported improvements in arch height, balance performance, and foot function following short foot exercise programmes (Kim and Kim, 2016; Lynn et al., 2012; Moon and Jung, 2021). As a result, short foot exercise has become a commonly recommended conservative intervention for individuals with flexible flat foot. In addition to exercise-based approaches, manual therapy interventions have gained increasing attention in the management of foot dysfunction. The talonavicular joint plays a critical role in foot mechanics and load transmission across the medial column of the foot. Restrictions in talonavicular mobility may alter load distribution and compromise arch support during functional activities. Talonavicular mobilization aims to restore normal joint motion, improve foot biomechanics, and facilitate optimal muscular activation (Mulligan, 2010; Maitland et

al., 2013). Restoration of joint mobility may enhance the effectiveness of exercise interventions by improving movement efficiency and neuromuscular control. Although previous studies have independently investigated the effects of gluteal strengthening, short foot exercise, and manual therapy interventions on foot posture and function, direct comparisons between gluteal muscle strengthening combined with talonavicular mobilization and short foot exercise combined with talonavicular mobilization remain limited. Furthermore, evidence regarding the preventive role of these interventions in preserving MLA integrity among young adults is scarce. Identification of the most effective physiotherapy strategy may contribute to improved clinical decision-making and prevention of future biomechanical complications associated with flexible flat foot. Therefore, the present study aimed to compare the effectiveness of gluteal muscle strengthening combined with talonavicular mobilization versus short foot exercise combined with talonavicular mobilization as a precautionary strategy for improving medial longitudinal arch integrity among young adults with flexible flat foot. It was hypothesized that gluteal muscle strengthening combined with talonavicular mobilization would produce greater improvements in Navicular Drop Test values than short foot exercise combined with talonavicular mobilization.

Material and Methods

Study Design- A randomized parallel-group pre-test and post-test comparative interventional study was conducted to evaluate the effectiveness of gluteal muscle strengthening combined with talonavicular mobilization compared with short foot exercise combined with talonavicular mobilization in improving medial longitudinal arch integrity among young adults with flexible flat foot. The study was carried out over a period of four weeks in the Department of Physiotherapy at Sree Abirami College of Physiotherapy, Coimbatore, Tamil Nadu, India. The study design was selected to allow direct comparison between two physiotherapeutic intervention approaches while minimizing allocation bias through randomization.

Ethical Approval- Prior to commencement of the study, ethical approval was obtained from the Institutional Ethics Committee of Sree Abirami College of Physiotherapy.

Ethical Approval Number: SACOPT/Ethical Clearance2134/2026

The study population consisted of young adults diagnosed with flexible flat foot who met the predefined eligibility criteria. Participants were recruited through convenience sampling from students and community volunteers who attended the physiotherapy department for screening and assessment. A total of twenty participants were recruited for the study and randomly allocated into two intervention groups.

Group A (n = 10): Gluteal muscle strengthening combined with talonavicular mobilization.

Group B (n = 10): Short foot exercise combined with talonavicular mobilization.

Inclusion Criteria

Participants were included in the study if they met the following criteria:

- Age between 18 and 25 years.
- Presence of unilateral or bilateral flexible flat foot.
- Navicular Drop Test value greater than 10 mm.
- Ability to understand and follow verbal instructions.
- Willingness to participate and provide informed consent.

Exclusion Criteria

Participants were excluded if they had:

- Rigid flat foot deformity.
- Previous surgery involving the foot or ankle.
- Neurological disorders affecting gait or balance.
- Recent lower extremity injury within the previous six months.

- Inflammatory joint disease.
- Congenital musculoskeletal abnormalities affecting lower limb alignment.
- Current participation in other foot rehabilitation programs.

Outcome Measure

Navicular Drop Test (NDT)- The Navicular Drop Test was used as the primary outcome measure to assess medial longitudinal arch integrity. The test was performed according to the procedure described by Brody (1982).

Procedure

- The participant was seated with both feet supported on the floor.
- The navicular tuberosity was identified and marked.
- The height of the navicular tuberosity from the floor was measured in subtalar neutral position.
- The participant then assumed a relaxed standing position.
- The navicular height was measured again.
- The difference between seated and standing measurements represented the navicular drop value.

Measurements were recorded in centimeters using a vernier caliper. Lower navicular drop values following intervention indicated improvement in medial longitudinal arch support. Outcome assessment was performed at:

- Baseline (Pre-test)
- After four weeks of intervention (Post-test)

Intervention Protocol

Both intervention groups received treatment five sessions per week for four consecutive weeks. Each treatment session lasted approximately thirty minutes.

Group A: Gluteal Muscle Strengthening with Talonavicular Mobilization

Participants assigned to Group A performed a structured gluteal strengthening program designed to improve proximal hip stability.

Exercise 1: Clam Shell Exercise

Position: Side-lying with hips flexed approximately 45 degrees and knees flexed 90 degrees.
Procedure: Participants lifted the upper knee while maintaining contact between the feet.
Dosage: 3 sets of 12 repetitions.

Exercise 2: Side-Lying Hip Abduction

Position: Side-lying with lower limb straight.
Procedure: Participants abducted the upper limb while maintaining neutral hip rotation.
Dosage: 3 sets of 12 repetitions.

Exercise 3: Prone Hip Extension

Position: Prone lying.
Procedure: Participants extended the hip while maintaining knee extension.
Dosage: 3 sets of 12 repetitions.

Exercise 4: Bridging Exercise

Position: Supine lying with knees flexed.
Procedure: Participants elevated the pelvis until the trunk and thighs formed a straight line.
Dosage: 3 sets of 12 repetitions.

Resistance Progression

Elastic resistance bands (TheraBand) were used. Resistance was progressively increased each week according to participant tolerance.

Talonavicular Mobilization
Following strengthening exercises, talonavicular mobilization was performed.
Technique
Maitland Grade III posteroanterior oscillatory mobilization.
Position
Participant: Supine lying.
Therapist: Stabilized the foot and applied oscillatory pressure over the talonavicular joint.
Dosage : Three sets , Thirty seconds per set, Ten seconds rest between sets

Group B: Short Foot Exercise with Talonavicular Mobilization

Participants assigned to Group B performed a short foot exercise program aimed at strengthening intrinsic foot muscles.

Short Foot Exercise
Weeks 1–2: Exercise performed in sitting.
Weeks 3–4: Exercise progressed to standing.
Procedure: Participants were instructed to shorten the foot by drawing the first metatarsal head toward the heel without flexing the toes. Care was taken to avoid toe curling and compensatory movements.
Dosage: Ten-second hold, Ten repetitions, Three sets

Talonavicular Mobilization
The same talonavicular mobilization protocol used in Group A was administered to Group B.
Dosage : Three sets , Thirty seconds per set, Ten seconds rest between sets

Statistical Analysis

Collected data were entered into Statistical Package for Social Sciences (SPSS) Version 25.0 for analysis. Descriptive statistics including mean and standard deviation were calculated for all outcome variables.
Within-Group Analysis: Paired t-tests were used to compare pre-test and post-test Navicular Drop Test values within each group.
Between-Group Analysis: Independent t-tests were used to compare post-test values between Group A and Group B.
The level of statistical significance was set at $p < 0.05$

Results

A total of twenty participants completed the study, and no dropouts were reported during the intervention period. Baseline comparison of Navicular Drop Test values demonstrated no statistically significant difference between the groups ($t = 0.5804$, $p = 0.569$), indicating that both groups were comparable before the intervention (Table 1).

Table 1. Baseline Comparison of Navicular Drop Test Values

Group	Mean (cm)	Standard Deviation	t-value	p-value
Group A	0.9260	0.0222	0.5804	0.569
Group B	0.9200	0.0240		

Within-group analysis demonstrated statistically significant improvements in both intervention groups following four weeks of treatment. In Group A, participants who received gluteal muscle strengthening combined with talonavicular mobilization showed a reduction in mean Navicular Drop Test values from 0.9260 ± 0.0222 cm at baseline to 0.6240 ± 0.0931 cm after intervention.

The mean difference was 0.3020 cm, and the improvement was statistically significant (t = 9.7833, p < 0.001) (Table 2).

Table 2. Within-Group Comparison of Navicular Drop Test Values in Group A

Time Point	Mean (cm)	Standard Deviation	Mean Difference	t-value	p-value
Pre-test	0.9260	0.0222	0.3020	9.7833	<0.001
Post-test	0.6240	0.0931			

Similarly, Group B participants who received short foot exercise combined with talonavicular mobilization demonstrated a reduction in mean Navicular Drop Test values from 0.9200 ± 0.0240 cm to 0.8460 ± 0.0395 cm following intervention. The mean difference was 0.0740 cm, and the improvement was statistically significant (t = 6.0110, p < 0.001) (Table 3).

Table 3. Within-Group Comparison of Navicular Drop Test Values in Group B

Time Point	Mean (cm)	Standard Deviation	Mean Difference	t-value	p-value
Pre-test	0.9200	0.0240	0.0740	6.0110	<0.001
Post-test	0.8460	0.0395			

Comparison of post-intervention outcomes between the two groups revealed a statistically significant difference. Participants in Group A demonstrated significantly lower Navicular Drop Test values compared with Group B following intervention (t = 6.9416, p < 0.001). The mean post-test difference between the groups was 0.2220 cm, indicating superior improvement in medial longitudinal arch integrity among participants who received gluteal muscle strengthening combined with talonavicular mobilization (Table 4).

Table 4. Between-Group Comparison of Post-Test Navicular Drop Test Values

Group	Mean (cm)	Standard Deviation	Mean Difference	t-value	p-value
Group A	0.6240	0.0931	0.2220	6.9416	<0.001
Group B	0.8460	0.0395			

Discussion

The present study was conducted to compare the effectiveness of gluteal muscle strengthening combined with talonavicular mobilization and short foot exercise combined with talonavicular mobilization in improving medial longitudinal arch (MLA) integrity among young adults with flexible flat foot. The findings demonstrated that both intervention protocols produced statistically significant improvements in Navicular Drop Test (NDT) values following four weeks of treatment. However, participants who received gluteal muscle strengthening combined with talonavicular mobilization exhibited significantly greater improvement than those who received short foot exercise combined with talonavicular mobilization. The significant reduction in NDT values

observed in Group A suggests that proximal strengthening may play a crucial role in improving foot posture and arch stability. The gluteus maximus and gluteus medius are important stabilizers of the pelvis and lower extremity during functional activities. Weakness of these muscles has been associated with increased femoral internal rotation and adduction, resulting in compensatory tibial internal rotation and excessive foot pronation (Powers, 2003; Kendall et al., 2005). By improving proximal control, gluteal strengthening exercises may reduce abnormal rotational stresses transmitted through the kinetic chain and facilitate maintenance of the medial longitudinal arch during weight-bearing activities. The findings of the present study are consistent with those reported by Goo et al. (2016), who demonstrated significant reductions in navicular drop and improvements in lower-extremity muscle activity following a strengthening programme targeting the gluteus maximus and abductor hallucis muscles in individuals with flexible flat foot. Similarly, Powers (2003) emphasized the importance of proximal hip musculature in controlling lower-extremity alignment and suggested that impaired hip muscle function may contribute to distal biomechanical dysfunction. The superior outcomes observed in Group A support the concept of regional interdependence, whereby proximal impairments influence distal joint mechanics and movement patterns. Although Group B also demonstrated statistically significant improvement following intervention, the magnitude of change was comparatively smaller. Short foot exercise primarily targets the intrinsic foot muscles responsible for dynamic stabilization of the MLA. Previous investigations have reported beneficial effects of short foot exercise on arch height, balance, and foot function (Kim and Kim, 2016; Lynn et al., 2012; Moon and Jung, 2021). Strengthening the intrinsic foot musculature enhances active support of the arch and may improve neuromuscular control during standing and walking activities. The improvements observed in Group B are therefore consistent with existing literature supporting the effectiveness of intrinsic foot muscle training. However, the relatively smaller improvement observed in Group B may be attributed to the limited duration of intervention. Structural and neuromuscular adaptations within the intrinsic foot muscles may require longer periods of training to achieve substantial biomechanical changes. In contrast, gluteal strengthening may produce broader biomechanical effects throughout the lower extremity by improving proximal stability and reducing compensatory pronatory stresses acting on the foot.

Talonavicular mobilization was administered to both intervention groups and may have contributed to the improvements observed in NDT values. The talonavicular joint plays a pivotal role in foot mobility and load transmission. Restrictions within this joint may compromise normal foot mechanics and contribute to arch dysfunction. Manual mobilization techniques have been proposed to restore normal joint movement, optimize load distribution, and facilitate muscular activation (Mulligan, 2010; Maitland et al., 2013). Therefore, the positive outcomes observed in both groups may partly reflect the beneficial effects of improved joint mobility in conjunction with exercise therapy. The findings of this study support previous evidence indicating that foot posture is influenced by factors extending beyond the local structures of the foot and ankle. Murley et al. (2009) reported that foot posture significantly affects lower-limb muscle activation patterns during gait, while McPoil and Cornwall (1996) demonstrated relationships between lower-extremity alignment and rearfoot motion. Collectively, these findings reinforce the importance of adopting a comprehensive biomechanical approach when managing individuals with flexible flat foot. From a clinical perspective, the results suggest that physiotherapists should consider incorporating proximal strengthening exercises into rehabilitation programmes for individuals with flexible flat foot. Traditional interventions frequently focus on intrinsic foot muscle training and orthotic support; however, the present findings indicate that addressing proximal deficits may produce greater improvements in arch integrity. Incorporation of gluteal strengthening exercises may therefore enhance treatment effectiveness and contribute to long-term biomechanical optimization.

Several strengths of the present study should be acknowledged. The randomized comparative design minimized allocation bias, and outcome assessment was performed by a blinded assessor, reducing measurement bias. Additionally, both intervention groups received identical talonavicular mobilization protocols, allowing comparison of the specific effects of the exercise interventions. The treatment programme was practical, cost-effective, and readily applicable in routine physiotherapy settings. Despite these strengths, certain limitations should be considered when interpreting the findings. The sample size was relatively small, limiting the generalizability of the results. The intervention period was restricted to four weeks, and long-term follow-up was not performed. Furthermore, dynamic biomechanical variables such as gait analysis, plantar pressure distribution, and functional performance outcomes were not assessed. Future studies involving larger samples, extended intervention periods, and comprehensive biomechanical assessments are recommended to further investigate the long-term effectiveness of these interventions. Overall, the present study provides evidence that gluteal muscle strengthening combined with talonavicular mobilization is more effective than short foot exercise combined with talonavicular mobilization in improving medial longitudinal arch integrity among young adults with flexible flat foot. These findings highlight the importance of proximal muscle function in maintaining optimal foot posture and support the integration of proximal strengthening strategies within contemporary physiotherapy practice.

Conclusion

The present study demonstrated that both gluteal muscle strengthening combined with talonavicular mobilization and short foot exercise combined with talonavicular mobilization significantly improved medial longitudinal arch integrity in young adults with flexible flat foot. Improvements were evidenced by significant reductions in Navicular Drop Test values following four weeks of intervention. However, participants who received gluteal muscle strengthening combined with talonavicular mobilization exhibited significantly greater improvement compared with those who received short foot exercise combined with talonavicular mobilization. These findings suggest that proximal hip strengthening may exert beneficial effects on distal foot biomechanics through improved lower-extremity alignment and kinetic chain control. The results support the incorporation of gluteal strengthening exercises into physiotherapy rehabilitation programmes aimed at preventing or managing flexible flat foot. Addressing proximal muscle dysfunction, in combination with appropriate manual therapy interventions, may provide a more comprehensive and effective strategy for preserving medial longitudinal arch integrity and optimizing lower-extremity function. Further research involving larger sample sizes, longer follow-up periods, and additional biomechanical outcome measures is recommended to confirm the long-term effectiveness and clinical applicability of these interventions.

Acknowledgements

The authors express their sincere gratitude to all participants who voluntarily participated in this study. The authors also acknowledge the support and guidance provided by the faculty members, management, and Institutional Ethics Committee of Sree Abirami College of Physiotherapy, Coimbatore, Tamil Nadu, India. Their encouragement and assistance were invaluable in the successful completion of this research.

References

Arndt A, Wolf P, Liu A, Nester C, Jones R, Lundberg A. Intrinsic foot kinematics measured in vivo during the stance phase of slow running. J Biomech. 2007;40(12):2672-2678.

Bae CH, Choe YW, Kim MK. Effects of different external loads on the activities of the gluteus maximus and biceps femoris during prone hip extension in healthy young men. J Korean Soc Phys Med. 2020;15(2):1-9.

Banwell HA, Paris ME, Mackintosh S, Williams CM. Paediatric flexible flat foot: how are we measuring it and are we getting it right? A systematic review. J Foot Ankle Res. 2018;11:21.

Bolton-Maggs BG. Sudden death and other events in sports: the role of screening. Br J Sports Med. 2008;42(6):419-420.

Brody DM. Techniques in the evaluation and treatment of the injured runner. Orthop Clin North Am. 1982;13(3):541-558.

Chaurasia BD. Human Anatomy. Vol. 2. 6th ed. New Delhi: CBS Publishers & Distributors; 2013.

Cote KP, Brunet ME, Gansneder BM, Shultz SJ. Effects of pronated and supinated foot postures on static and dynamic postural stability. J Athl Train. 2005;40(1):41-46.

Donatelli R. The Biomechanics of the Foot and Ankle. 2nd ed. Philadelphia: F.A. Davis Company; 1996.

Franco AH. Pes cavus and pes planus: analyses and treatment. Phys Ther. 1987;67(5):688-694.

Goo YM, Heo HJ, An DH. The effect of gluteus maximus and abductor hallucis strengthening exercises on navicular drop and lower extremity muscle activity. J Phys Ther Sci. 2016;28(3):826-829.

Hertel J, Gay MR, Denegar CR. Differences in postural control during single-leg stance among healthy individuals with different foot types. J Athl Train. 2002;37(2):129-132.

Jam B. Evaluation and retraining of the intrinsic foot muscles for pain syndromes related to abnormal control of pronation. Advanced Physical Therapy Education Institute. 2006:1-12.

Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA. Muscles: Testing and Function with Posture and Pain. 5th ed. Baltimore: Lippincott Williams & Wilkins; 2005.

Kim MH, Kim SH. The effects of short foot exercises and arch support insoles on improvement in the medial longitudinal arch. J Phys Ther Sci. 2016;28(11):3136-3139.

Kisner C, Colby LA, Borstad J. Therapeutic Exercise: Foundations and Techniques. 7th ed. Philadelphia: F.A. Davis Company; 2018.

Lynn SK, Padilla RA, Tsang KK. Differences in static- and dynamic-balance task performance after 4 weeks of intrinsic-foot-muscle training. J Sport Rehabil. 2012;21(4):327-333.

Magee DJ. Orthopedic Physical Assessment. 6th ed. St. Louis: Elsevier; 2014.

Maitland GD, Hengeveld E, Banks K, English K. Maitland's Vertebral Manipulation. 8th ed. Edinburgh: Elsevier Butterworth-Heinemann; 2013.

McPoil TG, Cornwall MW. Relationship between static lower extremity measurements and rearfoot motion during walking. J Orthop Sports Phys Ther. 1996;24(5):309-314.

Moon DC, Jung DY. The effects of short foot exercise on foot posture, balance, and lower extremity muscle activity in individuals with flexible flatfoot. Phys Ther Rehabil Sci. 2021;10(1):1-8.

Mulligan BR. Manual Therapy: NAGS, SNAGS, MWMS etc. 6th ed. Wellington: Plane View Services Ltd; 2010.

Murley GS, Menz HB, Landorf KB. Foot posture influences the electromyographic activity of selected lower limb muscles during gait. J Foot Ankle Res. 2009;2:35.

Neumann DA. Kinesiology of the Musculoskeletal System: Foundations for Rehabilitation. 3rd ed. St. Louis: Elsevier; 2017.

Norkin CC, White DJ. Measurement of Joint Motion: A Guide to Goniometry. 5th ed. Philadelphia: F.A. Davis Company; 2016.

Powers CM. The influence of altered lower-extremity kinematics on patellofemoral joint dysfunction: a theoretical perspective. J Orthop Sports Phys Ther. 2003;33(11):639-646.

Williams DS, McClay IS. Measurements used to characterize the foot and the medial longitudinal arch: reliability and validity. Phys Ther. 2000;80(9):864-871.

Conflict of Interest: None declared