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(EN) Evidence-based exercise therapy for flexible flatfoot: a narrative review.

[1]Pavel Křivan

[1]Jan Evangelista Purkyně University in Ústí nad Labem. Faculty of Health Studies, Department of Physiotherapy, Czech Republic.

**Corresponding author: pavel.krivan@ujep.cz*

SUMMARY/ABSTRACT

Starting point: Flexible flatfoot (FFF) is a common musculoskeletal condition, particularly in children, characterized by a decreased medial longitudinal arch that dynamically collapses under load. While often asymptomatic, FFF can contribute to pain, altered biomechanics, and functional limitations. Exercise therapy is frequently recommended as a conservative intervention, but the level of evidence supporting specific exercise strategies remains unclear.
Objective: This narrative review aims to summarize the current evidence on exercise-based interventions for FFF, focusing on their efficacy in improving foot structure, function, and symptomatology.
Methods: A comprehensive literature search was conducted in PubMed, Scopus and Web of Science to identify randomized controlled trials examining exercise therapy for FFF. Studies were analyzed based on intervention types, outcome measures, and overall effectiveness.
Results: The findings suggest that short foot exercise, toe exercises, foot supination exercises, sensorimotor training, plantar and dorsal flexion exercises, general lower limb exercises and core exercises may contribute to improved arch height, foot posture, and functional outcomes.
Conclusions: Exercise therapy appears to be a promising conservative approach for managing FFF, with potential benefits for foot function and posture. However, further high-quality randomized controlled trials with standardized protocols and long-term follow-up are needed to establish optimal exercise regimens and their long-term effects.

KEYWORDS
flexible flatfoot,
exercise therapy,
conservative treatment

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1 INTRODUCTION

Flexible flatfoot (FFF) is a common musculoskeletal condition characterized by a lowered medial longitudinal arch (MLA) and excessive foot pronation, particularly under weight-bearing conditions. Although FFF is often asymptomatic in childhood, it may contribute to biomechanical inefficiencies, musculoskeletal discomfort, and an increased risk of injuries in adulthood. Conservative management, particularly exercise therapy, plays a crucial role in improving foot function and mitigating associated complications.[1]

Recent systematic reviews highlight the efficacy of structured exercise programs in enhancing foot posture, strength, and proprioception in individuals with FFF. For instance, strengthening the posterior tibial and plantar muscles, combined with gluteus strengthening, neuromuscular movements centered on the hip, and lower-limb proprioceptive neuromuscular facilitation techniques, has been reported as effective in improving MLA morphology, while posterior tibial muscle training improved foot function.[2]

Despite these promising findings, variability in intervention protocols, small sample sizes, and methodological heterogeneity across studies limit the generalizability of results. Further research is necessary to establish standardized exercise regimens and to determine the long-term efficacy of conservative interventions for FFF.[3]

2 METHODS

To develop this narrative review, a literature search was conducted from January to February 2025. The following databases were used for the search: Scopus, Web of Science, and PubMed. The search was performed using the following keywords:

PubMed: *((Flexible flatfoot OR Flatfoot OR Flat feet) AND (conservative treatment OR exercise therapy OR physical therapy OR rehabilitation OR strengthening exercises OR non-surgical treatment OR pain management OR orthotic devices OR foot orthoses OR biomechanical intervention OR arch support OR functional outcomes))*

Scopus: *(Flexible flatfoot OR Flatfoot OR Flat feet) AND (conservative treatment OR exercise therapy OR physical therapy OR rehabilitation OR orthotic devices OR foot orthoses OR arch support OR non-surgical treatment) AND ("randomized controlled trial" OR "randomised controlled trial" OR RCT)*

Web of Science: *TS=(Flexible flatfoot OR Flatfoot OR Flat feet) AND TS=(conservative treatment OR exercise therapy OR physical therapy OR rehabilitation OR orthotic devices OR foot orthoses OR arch support OR non-surgical treatment) AND TS=("randomized controlled trial" OR "randomised controlled trial" OR RCT)*

One of the search criteria was the publication time frame from January 2020 to February 2025. The second criterion was the inclusion of only randomized controlled trials (RCTs). A total of 74 articles were identified. All retrieved articles were screened based on their title and abstract. Exclusion criteria included case reports, protocols, reviews, systematic reviews, and meta-analyses. Inappropriate articles and duplicates were removed. Only studies focusing on exercise therapy, including strengthening exercises and proprioceptive training, were included. After exclusion, 16 RCTs remained, which are listed in **Table 1**.

3 STARTING POINT, OBJECTIVE, TASKS

This narrative review aims to summarize the current evidence on exercise-based interventions for FFF, focusing on their efficacy in improving foot structure, function, and symptomatology.

4 RESULTS

Sixteen studies that met the criteria were reviewed. In studies shown, seven main categories of exercises for FFF were identified: short foot exercise (SFE), toe exercises (TE), foot supination exercises (FSE), sensorimotor training (SMT), plantarflexion and dorsiflexion exercises (PDFE), general lower limb exercises (GLLE) and core exercises (CE). Overview is shown in **Table 1**.

The study by Brijwasi and Borkar[4] investigated the effects of a comprehensive exercise program on foot alignment in individuals with FFF. Fifty-two participants were randomly assigned to either an experimental group (EG) (26 participants) or a control group (CG) (26 participants). The EG performed a 30-minute exercise program three times per week for six weeks, which included active PDFE, SFE, GLLE (focusing on gluteal muscles), and stretching. The CG performed only PDFE for the same period. After six weeks, the EG showed a significant improvement in navicular drop height and longitudinal arch angle compared to the CG. These results suggest that the comprehensive exercise program effectively improved foot alignment and potentially reduced the progression to symptomatic flatfoot.

The RCT by Elsayed et al.[5] evaluated the combined effects of SFE and shoe insoles (SI) in individuals with symptomatic FFF. Forty participants were randomized into an EG (20 participants) that performed SFE (three sets of 10 repetitions daily) in addition to wearing SI (eight hours per day) or a CG (20 participants) that used SI alone for six weeks. Results showed significant improvements in foot pressure, pain, and function over time in favor of the EG, which reported less pain and better function than the CG. Navicular drop improved equally in both groups. The study concluded that combining SFE with SI yields better pain relief, functional improvement, and foot pressure distribution than using SI alone, recommending this combined approach for effective FFF rehabilitation.

The pilot single-blind RCT by Okamura et al.[6] investigated the effects of SFE on static and dynamic foot kinematics in individuals with FFF. Twenty participants were randomized into an EG that performed progressive SFE three times per week for eight weeks or a CG that received no intervention. The EG showed significant improvements in calcaneal inversion/eversion as part of the foot posture index and reduced time for navicular height to reach its minimum value during gait, indicating an enhanced windlass mechanism.

The study concluded that SFE can effectively improve static foot alignment and temporal foot kinematics, offering potential benefits in preventing or treating pes planus-related injuries.

The RCT by Sánchez-Rodríguez et al.[7] investigated the effects of a nine-week strengthening program targeting intrinsic and extrinsic foot muscles, as well as core muscles, on foot posture in adults with pronated feet. Thirty-six healthy participants with pronated feet were randomly assigned to an EG (two 40-minute exercise sessions per week) or a CG. The EG showed a significant reduction in foot posture index, indicating improved foot posture, while the CG showed no change. The study concluded that a comprehensive strengthening program effectively improved foot posture in adults with pronated feet.

The RCT by Utsahachant et al.[8] evaluated the effects of SFE alone and combined GLLE on dynamic foot function in individuals with FFF. Forty-five participants were randomized into three groups: SFE, SFE + GLLE, and a CG. Both EGs completed a six-week daily home-based exercise program via telerehabilitation. After the intervention, both EGs demonstrated shorter times to the lowest MLA and improved MLA motion during the stance phase of gait. The second group also showed greater changes in pressure excursion index compared to the SFE and CG. Improvements in intrinsic foot muscle strength and navicular drop were observed in both intervention groups. The study concluded that both EG programs significantly enhanced dynamic foot function, with the combined SFE + GLLE program offering superior results, supporting their inclusion in corrective programs for FFF.

The RCT by Kirmizi et al.[9] investigated the effects of foot exercises, customized arch support insoles, and a combination of both on foot posture, plantar force distribution, and balance in individuals with FFF. Forty-five participants were randomly assigned to three groups: (1) exercise (FSE + SFE, three days per week for six weeks), (2) SI (customized arch support insoles used for six weeks), and (3) exercise plus SI. Assessments were conducted at baseline, six weeks, and twelve weeks. Results showed improvements in foot posture across all groups, with exercises and the combination therapy being more effective than SI alone. Changes in plantar force distribution were observed during standing and walking, with differences in effectiveness depending on plantar regions and walking speeds. Static balance improved in all groups, but limits of stability significantly improved in the exercise and combination groups.

The RCT by Abd-Elmonem et al.[10] examined the effects of corrective exercises combined with neuromuscular electrical stimulation (NMES) on clinical and radiological outcomes in children with FFF. Seventy-two children aged 7 to 12 years were randomly assigned to either an EG (corrective exercises and NMES) or a CG (same exercises and sham NMES), with both groups undergoing the program for four months (three sessions per week). Corrective exercises included SFE, TE, and FSE, and NMES (30 min) was applied to reinforce the plantar intrinsic foot muscles using a bipolar technique with the active electrode placed on the abductor hallucis and the passive electrode behind the first metatarsal head. High-voltage pulsed current was delivered at 85 Hz with 5 s contraction and 12 s rest intervals, and intensity was adjusted to individual tolerance without pain. CG received sham NMES with zero current. Outcome measures included Staheli's arch index (via footprint analysis), navicular drop (via the navicular drop test), and radiographic indices (via X-ray imaging). Significant improvements were observed in all measures within both groups; however, the EG demonstrated significantly greater improvements in Staheli's arch index, navicular drop, and radiographic indices for both feet compared to the CG. The study concluded that combining corrective exercises with NMES provides superior clinical and radiological benefits in children with FFF compared to exercises alone.

The study by Bac et al.[11] investigated the effects of myofascial release (MF), an exercise program, and their combination on pain and selected static and dynamic foot indicators in adults with FFF. A total of 60 participants were randomly assigned to four groups (15 per group): three EGs and one CG. The rehabilitation program lasted four weeks. The results showed a significant reduction in pain across all EGs, with the greatest improvements in the MF group. Static foot load distribution changes were significant only for selected indicators, while dynamic changes were observed exclusively in the EGs, particularly in the MF group and the MF + exercise program group. The findings suggest that MF, both alone and in combination with exercises, is effective in reducing pain in FFF, though its impact on foot mechanics remains limited.

The study by Suzuki et al.[12] examined the effects of SFE and TE on lower-limb motor control during single-leg standing (SLS) in university students with FFF. A total of 36 participants were randomly assigned to either the SFE or TE group and completed an eight-week intervention. Assessments included the navicular drop test, toe grip strength (TGS), plantar sensation, and various SLS parameters such as center of pressure (COP) amplitude, muscle onset times, joint angles, and pelvic shift. The results showed that the SFE group had significant improvements in TGS, COP in the mediolateral direction, and earlier activation of the gluteus maximus and gluteus medius muscles, whereas the TE group showed no significant changes. These findings suggest that SFE enhances neuromuscular control in individuals with FFF, making it a potentially beneficial intervention for improving postural stability.

The study by Park et al.[13] investigated the effects of rhythm step training (RST) on foot and lower limb balance in children and adolescents with FFF using radiographic analysis. A total of 160 participants were randomly assigned to either the RST group or the general flat feet training (GFFT) group, completing 50-minute exercise sessions once a week for 12 weeks. Quadriceps angle, calcaneal pitch angle, calcaneal-first metatarsal angle, and navicular-cuboid overlap ratio were measured pre- and post-intervention. The results demonstrated significantly greater improvements in all measured parameters in the RST group compared to the GFFT group, indicating that RST is more effective in normalizing calcaneal biomechanics and enhancing lower limb function. These findings suggest that RST may serve as an effective intervention for improving foot and lower limb balance in children and adolescents with FFF, though further research is needed to evaluate the specific contributions of RST components.

The study by Gabriel et al.[14] examined the local, remote, and contralateral effects of a four-week intrinsic foot muscle exercise intervention on foot parameters, flexibility, and posterior chain performance in 28 recreationally active adults. Participants were randomly assigned to either a CG or an EG that performed unilateral foot exercises for 2 × 6 minutes twice daily, at least five days per week. Assessments were conducted at baseline, post-intervention, and after a four-week washout period. The EG showed significant improvements in the Foot Posture Index-6 score for both the trained (26% improvement) and untrained leg (11% improvement), with the trained leg maintaining improvements after the four-week washout period. Ankle range of motion and balance of the trained leg improved significantly after the four-week washout period, while other parameters showed no significant changes. The findings suggest that a four-week foot exercise program yields local but not remote effects in healthy young adults.

The study by Gabriel et al.[15] investigated the local and remote effects of a four-week minimalist shoe (MS) walking intervention on foot posture, balance, and posterior chain function in 28 recreationally active young adults. Participants were randomly assigned to an EG, which gradually increased their MS walking from 3,000 steps per day in the first week to 5,000 steps per day for the remaining three weeks, or a CG that walked in their preferred shoes. Assessments were conducted at baseline, post-intervention, and after a four-week washout period. The EG showed significant improvements in the FPI and static single-leg stance balance post-intervention, with improvements persisting after four weeks. However, no significant changes were found in ankle, foot, or posterior chain range of motion and strength. The results suggest that a four-week MS walking intervention can enhance foot posture and balance in young adults, but no chronic remote effects on the posterior chain should be expected.

The RCT by Engkananuwat and Kanlayanaphotporn[16] examined the effects of an eight-week SFE, FSE and GLLE program versus SFE and FSE alone on MLA parameters in 52 individuals with bilateral FFF. Participants were randomly assigned to either a foot EG or a foot + hip EG. Measurements were taken at baseline, four weeks, and eight weeks. At four weeks, the foot + hip EG demonstrated significantly less navicular drop, reduced plantar pressure at the medial forefoot, and lower mediolateral displacement, while exhibiting a greater arch height index compared to the foot EG. By eight weeks, this group also showed significantly lower plantar pressure at the medial hindfoot and reduced anteroposterior displacement. However, no significant differences in dynamic balance were observed between groups. The findings suggest that incorporating gluteus medius strengthening exercises enhances MLA support more effectively than foot exercises alone.

The RCT by Moon and Jung[17] investigated the effects of combining SFE with SMT on postural stability in individuals with FFF. A total of 32 participants were randomly assigned to either the SMT + SFE group or the SMT-alone group, completing 18 training sessions over six weeks. Results showed that both static and dynamic balance improved significantly more in the SMT + SFE group compared to SMT alone, while no significant differences were observed in the Hmax/Mmax ratio. These findings suggest that integrating SFE into balance rehabilitation enhances postural stability in individuals with flatfoot more effectively than SMT alone.

The RCT by Gheitasi et al.[18] examined the effectiveness of intrinsic versus extrinsic foot muscle exercises in improving the MLA in adolescents with FFF. Thirty-six adolescents were randomly assigned to three groups: an intrinsic muscle EG, an extrinsic muscle EG, and a CG (no intervention). Results showed a significant reduction in navicular drop in both EGs compared to the CG, with the intrinsic muscle EG demonstrating greater improvements than the extrinsic muscle EG. These findings suggest that exercises targeting intrinsic foot muscles (SFE and TE) are more effective for correcting FFF in adolescents.

The non-RCT by Molina-Garcia et al.[19] investigated the effects of a 13-week integrative neuromuscular training program on gait biomechanics in 50 children (mean age 10.77 years) with overweight/obesity. Participants were divided into an EG, which performed strength and aerobic training (three times per week), and a CG that maintained their usual lifestyle for 13 weeks. While the CG showed increased foot abduction, pelvic anterior tilt, and ankle abduction angles, these alterations were not present in the EG. The findings suggest that neuromuscular training may help mitigate biomechanical gait alterations in children with overweight/obesity, potentially preventing movement-related musculoskeletal disorders.

5 DISCUSSION

SFE is a specific foot exercise designed to strengthen the intrinsic muscles of the foot, particularly the abductor hallucis, flexor digitorum brevis, and quadratus plantae. It is primarily used to improve foot arch control, enhance proprioception, and support postural stability. SFE is commonly incorporated into rehabilitation programs for conditions such as FFF, plantar fasciopathy, and lower limb biomechanical dysfunctions. The exercise involves actively shortening the foot by pulling the metatarsal heads toward the heel without curling the toes, promoting MLA activation and foot intrinsic muscle engagement. The present review indicates that SFE is currently the most extensively researched exercise for FFF. Various studies have employed SFE with relatively consistent protocols, while others have incorporated modifications to fit their specific study populations or treatment programs. Usually, the exercise was performed in a seated or standing position. Participants were instructed to pull the metatarsal heads towards the heel to activate the foot's intrinsic muscles without flexing the toes. The position was held for 5 seconds and repeated for 3–5 sets of 10 repetitions. The exercise was usually performed 3–5 times per week. Applying SFE alone showed better results compared to CG (no intervention), TE, or SI.[5,6,8,12] In case of combining SFE with other exercises, it yields even better results: several studies[4,8–11,14,16–18] combined SFE with other mentioned exercises. In every case, this combination showed superior results.

TE is a simple rehabilitation exercise focused on strengthening the muscles of the toes and enhancing foot function. It primarily targets the flexor and extensor muscles of the toes (including the flexor hallucis longus and flexor digitorum longus). This exercise is often used in the treatment of conditions like toe deformities, plantar fasciitis, and FFF. The exercise typically involves active movements such as toe curls, extensions, and spread-outs, picking up small objects with the toes, or towel gathering with weights.[7,10,18] TE was usually performed 2–5 times per week for 10–30 repetitions with a 5-second hold, mostly depending on the total training session volume. TE alone was examined only by Suzuki et al.[12] and compared to SFE, it was less effective but still showed better results than CG with no intervention. In combination with other mentioned exercises, TE was examined by several studies[7,10,11,13,14,18] and their results showed that TE seems to be effective, but it should be added to SFE for best results.

FSE focuses on strengthening the muscles responsible for the supination movement of the foot. This exercise primarily targets the tibialis posterior muscle, which is essential for maintaining the MLA by reducing the navicular drop when the foot is loaded. This exercise can be performed in two variations. In the first option, the exercise typically involves the participant standing with the forefoot on the edge of a step while the foot is held in a supinated position. The individual may be instructed to hold this position for several seconds, engaging the muscles to stabilize the foot.[7,9,10] The other option is using a resistance band and performing foot supination (as a part of foot adduction) in an open kinetic chain.[11,16] Participants were instructed to sit on a chair with their feet off the ground and knees bent at 90 degrees. They were tasked to slowly rotate the foot (supinate) while keeping the heel planted, hold for 2–5 seconds, then return to the starting position. 2–3 sets of 10–15 reps per foot.

PDFE targets the muscles of the lower leg, specifically the calf muscles (gastrocnemius, soleus) for plantar flexion and the tibialis anterior for dorsal flexion. These movements can be performed in an open kinetic chain with an added resistance band[4,18] or in a closed kinetic chain via calf raises for plantar flexion.[13] Both plantar and dorsal flexors of the ankle can also be exercised via walking on toes or heels.[7] For example, 2 sets of 15 reps (with 10 seconds of contraction duration) of PDFE were performed 3 times per week in a study by Brijwasi and Borkar.[4] Another example is a study by Park et al.[13] – in this study, calf raises were performed in 3 sets of 10 reps with 5 seconds of holding contraction (once per week).

SMT is a therapeutic approach aimed at improving neuromuscular control, proprioception, and postural stability through specific exercises targeting the sensorimotor system. It involves dynamic and static balance tasks, coordination drills, and controlled perturbations to enhance sensory feedback and motor responses. Moon et al.[17] examined this approach to FFF therapy and concluded that adding SFE to SMT brings better results than training SMT alone, with significant effects on static and dynamic postural stability. In this program, exercises like single leg stance, squat, lunge or jump on fixed surface were used, while there was a gradual progression to unstable surfaces. Training parameters were 3 exercises per session, each exercise was performed in 3 sets of 10 reps or 30 second hold, 3 times per week. Unspecified balance training was also implemented in another two studies[7,13] proving that SMT is a useful addition.

GLLE encompasses a range of strengthening and mobility exercises targeting the muscles of the lower extremities to enhance stability, alignment, and functional movement patterns. Brijwasi and Borkar[4] implemented gluteal muscle strengthening via hip abduction and extension (side and prone lying), performing 2 sets of 8–12 reps in 3 sessions per week. Contraction duration was progressively increased up to 10 seconds. In conclusion, adding these exercises led to better results in managing FFF. Utsahachant et al.[8] added wall squat and unilateral wall squat as a progression when exercising SFE. This exercise difficulty was also increased via adding sets, reps and/or holding time. In conclusion, adding these lower limb exercises led to improved proximal muscle control and center of pressure index during gait. Engkananuwat and Kanlayanaphotporn[16] added hip abductor exercise ("the clamshell"). For progressions, increasing load was used to train the gluteus medius muscle. Exercise was performed 5 days per week for 8 weeks. In conclusion, adding this exercise to SFE and FSE was beneficial. Park et al.[13] examined GLLE like squats, lunges and step-ups compared to RST, consisting of a variety of stepping and jumping exercises. Exercises were performed once a week for 12 weeks in 3 sets of 30 reps, starting with easier exercises and progressing to more difficult ones. Gheitasi et al.[18] implemented exercises to strengthen hip extension, abduction and external rotation along with PDFE, showing better results compared to CG (no intervention), but it was less effective than SFE combined with TE for FFF.

CE can play a crucial role in improving postural stability and neuromuscular control, which are essential for maintaining proper lower limb alignment and potentially foot biomechanics in individuals with FFF. Targeted exercises (planks, dead bugs, bird dogs, etc.) strengthen the deep core musculature, including the transversus abdominis, multifidus, and obliques. Sánchez-Rodríguez et al.[7] implemented CE as an addition to PDFE, FSE, TE and SMT. This whole exercise program showed better results than a CG with no intervention. As part of a global exercise program, some CE were also included in two studies[13,19] but it is not possible to determine whether the intervention had a benefit.

Despite providing valuable insights into exercise-based interventions for FFF, this review has several limitations. Future research should focus on well-designed RCTs with standardized protocols, larger sample sizes, and extended follow-up periods to enhance the reliability and applicability of findings. This review can serve as a basis for future research focusing on the effectiveness of exercise therapy in different age groups or when categorized according to somatometric parameters.

6 CONCLUSIONS

The findings suggest that SFE, TE, FSE, SMT, PDFE, GLLE and CE may contribute to improved arch height, foot posture, and functional outcomes in individuals with FFF. Sensorimotor exercises enhance proprioception and neuromuscular control, while targeted foot muscle strengthening supports the MLA. Additionally, core and lower limb exercises address kinetic chain imbalances that may influence foot mechanics. However, variations in study design, small sample sizes, and heterogeneous methodologies limit the generalizability of results.

7 ZUSAMMENFASSUNG

Ausgangspunkt: Der flexible Plattfuß ist eine häufige muskuloskelettale Erkrankung, insbesondere bei Kindern, die durch ein verringertes mediales Längsgewölbe gekennzeichnet ist, das unter Belastung dynamisch kollabiert. Obwohl FFF häufig asymptomatisch verläuft, kann er zu Schmerzen, veränderter Biomechanik und funktionellen Einschränkungen beitragen. Bewegungstherapie wird häufig als konservative Intervention empfohlen, jedoch bleibt die Evidenzlage für spezifische Übungsstrategien unklar.

Ziel: Diese narrative Übersichtsarbeit zielt darauf ab, die aktuelle Evidenz zu bewegungstherapeutischen Interventionen bei flexible Plattfuß zusammenzufassen, mit Schwerpunkt auf deren Wirksamkeit hinsichtlich der Verbesserung von Fußstruktur, -funktion und Symptomatik.

Methoden: Eine umfassende Literaturrecherche wurde in den Datenbanken PubMed, Scopus und Web of Science durchgeführt, um randomisierte kontrollierte Studien zur Bewegungstherapie bei flexible Plattfuß zu identifizieren. Die Studien wurden in Bezug auf die Art der Interventionen, die verwendeten Ergebnismaße und die Gesamtwirksamkeit analysiert.

Ergebnisse: Die Ergebnisse deuten darauf hin, dass Kurzwußübungen, Zehenübungen, Fußsupinationsübungen, sensomotorisches Training, Übungen zur plantaren und dorsalen Flexion, allgemeine Übungen für die untere Extremität sowie Rumpfübungen zur Verbesserung der Gewölbehöhe, der Fußhaltung und der funktionellen Ergebnisse beitragen können.

Schlussfolgerungen: Bewegungstherapie stellt einen vielversprechenden konservativen Ansatz zur Behandlung von flexible Plattfuß dar, mit potenziellen Vorteilen für Fußfunktion und -haltung. Es sind jedoch weitere qualitativ hochwertige randomisierte kontrollierte Studien mit standardisierten Protokollen und langfristiger Nachbeobachtung erforderlich, um optimale Übungsregime und deren Langzeiteffekte festzulegen.

8 SUPPLEMENTARY

Table 1 - studies reviewed (overview).

Title	Authors (ref)	Study design (duration)	Sample (age)	Main results
A comprehensive exercise program improves foot alignment in people with flexible flat foot: a randomised trial	Brijwasi and Borkar[4]	1st group: SFE, PDFE, GLLE, Stretching 2nd group: PDFE (3×W, 6W)	52 (18-21)	Both groups improved; 1st group had significantly greater reductions in navicular drop height (0.4 cm, 95% CI 0.4–0.5) and increases in longitudinal arch angle (16°, 95% CI 13–19) vs. 2nd group.
The combined effect of short foot exercises and orthosis in symptomatic flexible flatfoot: a randomized controlled trial	Elsayed et al.[5]	1st group: SFE+SI 2nd group: SI (8W)	37 (26.8 ± 6.5) (24.9 ± 4.7)	Both groups improved; 1st group (SFE+SI) had significantly less pain ($p = 0.002$) and better function ($p = 0.03$) than 2nd group (SI alone). Navicular drop decreased equally in both groups.
Effects of plantar intrinsic foot muscle strengthening exercise on static and dynamic foot kinematics: A pilot randomized controlled single-blind trial in individuals with pes planus	Okamura et al.[6]	1st group: SFE 2nd group: No intervention (3×W, 8W)	20 (19.7 ± 0.9) (20.2 ± 1.5)	1st group showed significant improvements in foot posture index (calcaneal inversion/eversion, $p < 0.05$) and reduced time to minimum navicular height during gait ($p < 0.01$), indicating improved windlass mechanism.

Modification of Pronated Foot Posture after a Program of Therapeutic Exercises	Sánchez-Rodríguez et al.[7]	1st group: PDFE, FSE, TE, SMT, CE 2nd group: No intervention (2×W, 9W)	36 (22.6 ± 4.4)	1st group showed significant improvement in foot posture index (FPI reduced from 8.1 to 6.4; p = 0.001), while 2nd group (control) showed no change (p = 1.0).
Effects of short foot exercise combined with lower extremity training on dynamic foot function in individuals with flexible flatfoot: A randomized controlled trial	Utsahachant et al.[8]	1st group: SFE 2nd group: SFE, GLLE 3rd group: No intervention (40 sessions, 6W)	45 (20-22)	Both 1st and 2nd groups showed significant improvements in MLA motion and intrinsic foot strength (p < 0.05). SFE+GLLE produced greater improvements in CPEI compared to SFE and control (p < 0.05).
Effects of foot exercises and customized arch support insoles on foot posture, plantar force distribution, and balance in people with flexible flatfoot: A randomized controlled trial	Kirmizi et al.[9]	1st group: SFE, FSE 2nd group: SI (customized) 3rd group: Both interventions (3×W, 6W)	40 (18-35)	Foot posture and plantar force distribution improved significantly in all groups (p < 0.05); SI alone was less effective than exercise or exercise+SI. Static balance improved in all groups, but limits of stability improved only in 1st and 3rd groups (p < 0.05).
Clinical and radiological outcomes of corrective exercises and neuromuscular electrical stimulation in children with flexible flatfeet: A randomized controlled trial	Abd-Elmonem et al.[10]	1st group: SFE, TE, FSE, NMES 2nd group: Same exercises, Sham NMES (3×W, 4M)	72 (7-12)	Both groups improved significantly from baseline; 1st group had greater improvements in arch index, navicular drop and radiographic measures vs. 2nd group (p < 0.05).
The influence of myofascial release on pain and selected indicators of flat foot in adults: a controlled randomized trial	Bac et al.[11]	1st group: Myofascial release (2×W, 4W) 2nd group: Stretching, SFE, TE, FSE (5×W, 4W) 3rd group: Both interventions 4th group: No intervention (4W)	60 (20-49)	Significant pain reduction observed in intervention groups (p < 0.05), greatest in 1st group vs. 4th group. Static and dynamic foot load distribution improved mainly in 1st group, with limited significant between-group differences (p < 0.05).
Effect of short foot exercise on lower-limb motor control function during single-leg standing in university	Suzuki et al.[12]	1st group: SFE 2nd group:	36 (22-25)	1st group (SFE) showed significant improvements in toe grip strength (p < 0.001), mediolateral COP (p = 0.039),

students with flatfoot: A randomized controlled trial		TE 3rd group: No intervention (1×D, 8W)		and earlier activation of gluteus maximus ($p = 0.015$) and medius ($p < 0.001$). 2nd group (TE) showed no significant changes.
Effects of Rhythm Step Training on Foot and Lower Limb Balance in Children and Adolescents with Flat Feet: A Radiographic Analysis	Park et al.[13]	1st group: Stretching, Foam rolling, TE, PDFE, SMT, GLLE, Step box exercises 2nd group: Stretching, Foam rolling, TE, PDFE, CE, Jump exercises, Rhythm step training (1×W, 12W)	160 (6-13)	2nd group showed significantly greater improvements in Q-angle, CPA, CFMA, and navicular–cuboid overlap ratio vs. 1st group (all $p < 0.001$). 2nd group intervention was more effective in normalizing calcaneal biomechanics and improving lower limb function.
Local and non-local effects (on the posterior chain) of four weeks of foot exercises: a randomized controlled trial	Gabriel et al.[14]	1st group: SFE, TE 2nd group: No intervention (5×W, 4W)	28 (25.90 ± 4.34)	1st group improved Foot Posture Index-6 in trained (−26%, $p < 0.001$) and untrained leg (−11%, $p = 0.02$), with effects maintained at follow-up. Trained leg also showed significant gains in ankle ROM ($p = 0.02$) and balance ($p = 0.007$). No changes in 2nd group (control).
A four-week minimalist shoe walking intervention influences foot posture and balance in young adults–a randomized controlled trial	Gabriel et al.[15]	1st group: Minimalistic shoes 2nd group: No intervention (4W)	28 (25.3 ± 5.3)	MS walking group improved Foot Posture Index ($p < 0.001$) and balance ($p = 0.01$) after 4 weeks; effects maintained at follow-up (4-week wash-out period) ($p < 0.05$). No significant changes in other parameters or 2nd group (control).
Gluteus medius muscle strengthening exercise effects on MLA height in individuals with flexible flatfoot: a randomized controlled trial	Engkananuwat and Kanlayanaphotporn[16]	1st group: SFE, FSE 2nd group: SFE, FSE, GLLE (5×W, 8W)	52 (18-39)	Both groups improved, but 2nd group showed significantly greater effects: reduced ND ($p = 0.002$), and increased AHI ($p = 0.019$). No between-group difference in dynamic balance.
Effect of Incorporating Short-Foot Exercises in the Balance Rehabilitation of Flat Foot: A Randomized Controlled Trial	Moon and Jung[17]	1st group: SMT 2nd group: SFE, SMT (3×W, 6W)	32 (19-29)	Both groups improved. 2nd group showed significantly greater gains in static and dynamic balance vs. SMT alone ($p < 0.05$).

Corrective exercise for intrinsic foot muscles versus the extrinsic muscles to rehabilitate flat foot curving in adolescents: randomized-controlled trial	Gheitasi et al.[18]	1st group: SFE, TE 2nd group: PDFE, GLLE 3rd group: No intervention (3×W, 8W)	36 (12-16)	Both exercise groups showed significant improvements in navicular drop ($p < 0.05$) vs. control group. 1st group had significantly greater improvements than 2nd group.
Effects of integrative neuromuscular training on the gait biomechanics of children with overweight and obesity	Molina-Garcia et al.[19]	1st group: General EP 2nd group: No intervention (3×W, 13W)	50 (10.77 ± 1.24)	1st group maintained stance and single-limb support times and foot abduction angle, while 2nd group (control) worsened (group differences: 3.1 cs, 1.9 cs, 3.9°; $p < 0.05$). 1st group prevented increases in pelvic tilt (+7.7°) and ankle abduction (+4.6°) seen in 2nd group. No other significant changes.

Note: SFE = short foot exercise; TE = toe exercises; FSE = foot supination exercises; SMT = sensorimotor training; PDFE = plantarflexion and dorsiflexion exercises; GLLE = general lower limb exercises; CE = core exercises; MLA = medial longitudinal arch; M = month; W = week; D = day; FFF = flexible flatfoot; EP = exercise program; SI = shoe insoles; CPEI = center of pressure excursion index; CI = confidence interval; COP = center of pressure; CPA = calcaneal pitch angle; CFMA = calcaneal-first metatarsal angle; ROM = Range of Motion; AHI = arch height index; ND = navicular drop; NMES = neuromuscular electrical stimulation

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