

## Review Article

# The effects of short foot exercises to treat flat foot deformity: A systematic review

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### Abstract.

**BACKGROUND:** Studies on the effects of performing short foot exercises (SFEs) on the medial longitudinal arch (MLA) have been inconclusive.

**OBJECTIVE:** This study aimed to conduct a systematic review of the effects of SFEs.

**METHODS:** ‘SFE’ and ‘intrinsic foot muscle’ were keywords used to search for randomized controlled trials. One researcher screened relevant articles based on their titles and abstracts, and two independent researchers closely read the texts, accepting nine studies for inclusion. Outcomes, intervention duration, frequency, and the number of interventions were investigated.

**RESULTS:** Of 299 potential studies identified, the titles and abstracts of 211 studies were reviewed, and 192 were excluded. The full texts of 21 studies were obtained and evaluated according to inclusion and exclusion criteria. Nine studies met the inclusion criteria. Six studies concerning the MLA were identified, with four reporting MLA improvement. There was no consensus concerning the number and frequency of SFEs performed, and the mechanism of MLA improvement was unclear. MLA improvement was observed in participants who undertook  $\geq 5$  weeks of interventions.

**CONCLUSIONS:** The results suggest that performing SFEs for  $\geq 5$  weeks is effective in improving the MLA. Randomized controlled trials with details concerning the number and frequency of treatments are required.

Keywords: Flat feet, intrinsic foot muscles, medio-lateral arch, short foot exercise

## 1. Introduction

### 1.1. Flat foot deformity

Flat foot deformity is a chronic foot condition that includes flattening of the medial longitudinal arch (MLA), hindfoot valgus, and midfoot abduction [1], with a reported prevalence of 2–23% in adults [2]. The follow-

ing factors have been associated with flat feet: occupation [2], obesity [3], and age [4]. Recently, injuries to foot ligaments [5] and a decreased muscle cross-sectional area of the intrinsic foot muscles (IFMs) [6] have also been reported in flat feet, suggesting that foot function is impaired. Studies comparing flat feet with normal alignment have reported that flat feet involve a higher incidence of plantar tendinitis [7]. Furthermore, flat feet have been cited as an important etiology of several lower extremity overuse injuries, including low back pain [8] and shin splints [9,10]. Therefore, treating a flat foot deformity may potentially prevent overuse injuries.

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### 1.2. Treatment for flat foot deformity

Flat feet have previously been classified as flexible or rigid [11]. For rigid flat feet, surgical treatment to correct the bony structure is common [12]. For flexible flat feet, clinically asymptomatic cases do not require intervention [13]. For symptomatic cases, conservative therapy such as nonsteroidal anti-inflammatory drugs, weight loss, functional foot orthoses, physical therapy, and exercise therapy remain treatments of choice to relieve pain and prevent progression of the deformity [14,15]. Exercise therapy for flat feet includes extrinsic muscle and IFM strengthening to maintain the MLA [16,17]. The effects of toe flexion exercises, such as the toe curl exercise (TCE), have also been reported [18]. However, the TCE involves the use of both IFMs and extrinsic foot muscles, and recent studies have focused on the IFMs alone [19–21]. It has been reported that patients with flat feet have higher incidence rates of IFM atrophy compared with patients with a normal MLA [7] and there is a correlation between cross-sectional areas of atrophied IFMs, such as the abductor hallucis longus and flexor digitorum brevis muscles, and the severity of flat feet [22]. Short foot exercises (SFEs) have been used as exercise therapy for IFMs.

### 1.3. Short foot exercises

SFEs shorten the length of the foot through contracting the plantar muscles of the foot to pull the first metatarsal towards the heel and heighten the MLA without flexing the toes [23]. In flatfoot deformity, SFEs are used to strengthen the IFMs, which maintain the MLA [24,25]. Okamura reported that this exercise decreased foot posture index (FPI) values [26]. In chronic ankle instability, an eight-week SFE intervention was shown to increase Cumberland Ankle Instability Tool (CAIT) values [27].

Prior studies have reported that some patients cannot perform SFEs satisfactorily, even after two weeks of practice [28], and that this is one of the most difficult exercise therapies to implement. In addition, studies on the effect of SFEs on MLA improvement in patients with flat feet have reported differing outcomes [29] and this area remains contentious. Furthermore, the number and frequency of SFEs performed, the duration of the intervention, and the types of outcomes evaluated have not been fully investigated.

### 1.4. Study purpose

The purpose of this study was to conduct a systematic review of studies that provided full details concern-

ing the number and frequency of SFEs undertaken, the duration of the intervention, and the types of outcomes, along with the effects of SFEs.

## 2. Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement and was registered in the PROSPERO database under the identification number CRDCRD42020183467.

### 2.1. Search method

A combination of the following keywords and their variation were used: (short foot exercise OR (short or foot or exercise) OR SFE) AND (intrinsic muscle OR (intrinsic or muscle) OR IFM) to search for randomized controlled trials (RCTs) up to October 2021. We used PubMed, Physiotherapy Evidence Database (PEDro), and the Cochrane Library (including Cochrane Central Register of Controlled Trials, CENTRAL) as search databases. Two reviewers independently conducted the search.

### 2.2. Inclusion and exclusion criteria

The target studies were selected in terms of the abstracts of related articles identified during the database search. The retrieved studies were screened to determine their relevance. Inclusion criteria comprised: (i) RCTs, (ii) studies that included at least one group using an SFE as an intervention, and (iii) articles published in English. Exclusion criteria comprised: (i) animal experiments, and (ii) abstracts, letters, reviews, systematic reviews, meta-analyses, or case reports.

### 2.3. Quality assessment

The selected studies were independently and critically reviewed and evaluated by two reviewers using the Cochrane risk of bias tool for randomised trials (RoB 2.0), to assess the methodological quality of the included studies for risk of bias across five domains: (i) the randomization process, (ii) deviations from intended interventions, (iii) missing outcome data, (iv) measurement of the outcomes, and (v) selection of the reported results. Studies with a low risk of bias in all five domains were considered to have a low risk of overall bias, studies with some concerns in at least one

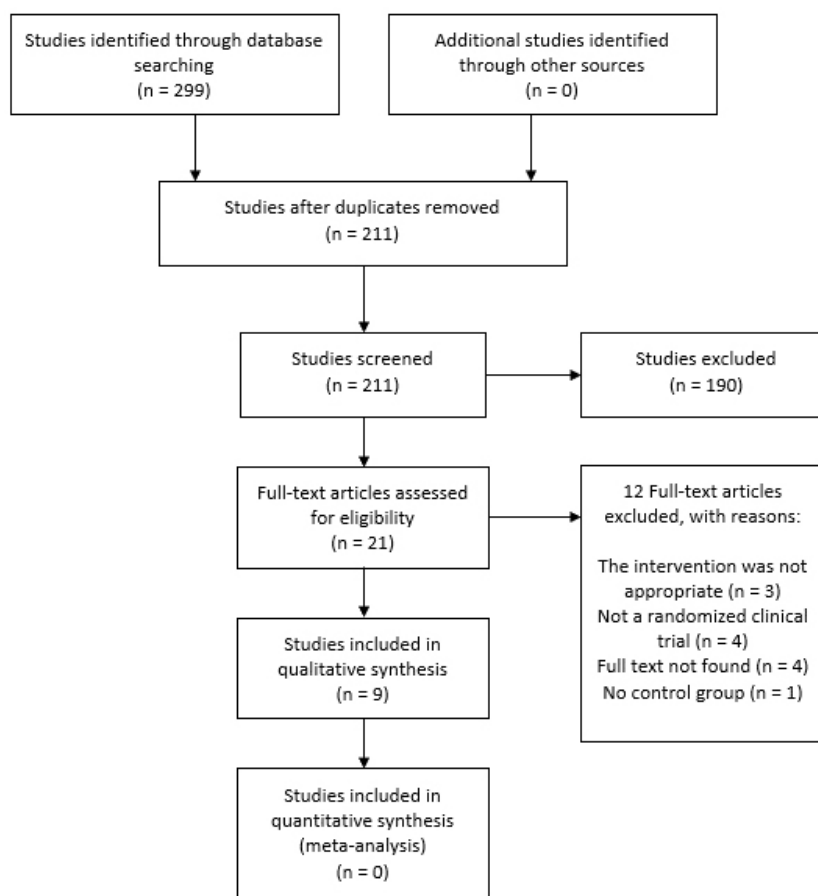


Fig. 1. Flowchart for the selection of included trials.

domain were considered to have some concerns overall, and studies with a high risk of bias overall or a high risk of bias in at least one domain were considered to have a high risk of bias. Studies with at least one domain of some concern were considered to have a concern overall, whereas those with at least one domain of a high risk of bias or studies with multiple domains of some concern were considered to have a high risk of bias. Disagreements among the reviewers were resolved through discussion [30].

#### 2.4. Data extraction

A meta-analysis was conducted on dynamic balance, specifically the Y-balance test. One reviewer extracted all the relevant data separately. The extracted and tabulated data included the lead author, year of publication, the number of participants, total score (number of SFEs, frequency of intervention, duration of intervention), type of muscle contraction, posture of execution, duration of muscle contraction, and type of outcome.

Total score = [duration of intervention (weeks) × frequency of intervention (times/week) × number of repetitions (times) × number of sets].

The amount of load was also compared.

#### 2.5. Statistical analysis

This meta-analysis was performed using Review Manager Version 5.4 software. Statistical calculations were performed for all included studies using detailed data for SFE alone, SFE combined with other exercise therapies, and exercise therapies alone. An SFE group (SFE combined with exercise therapy) and an exercise therapy group (exercise therapy only) were compared using a random-effects model. Statistical reliability was calculated using 95% confidence intervals (CIs). Statistical heterogeneity was assessed using  $I^2$  [31] and a random-effects model [32]. The significance level was set at < 5%, and  $P$ -values < 0.05 were considered statistically significant.

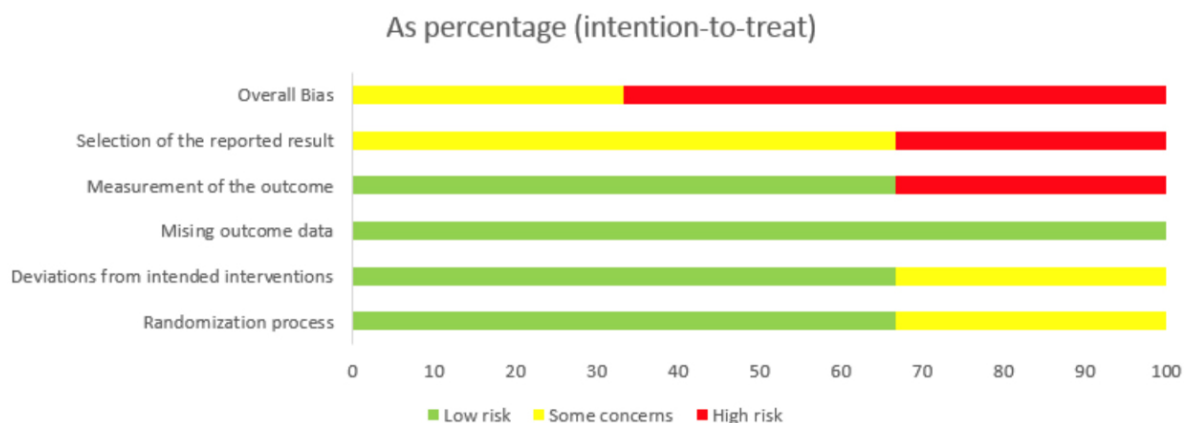


Fig. 2. Risk of bias graph: a review of authors’ evaluations concerning each risk of bias item presented as percentages across all included studies.

Study ID	D1	D2	D3	D4	D5	Overall	
Do young jung 2011	!	!	+	+	!	!	+
Kim Eun-Kyung 2016	!	-	+	+	!	-	!
John J Fraser 2017	+	-	+	+	!	-	-
Kazunori Okamura 2019	+	+	+	+	!	!	
Preetha Ramachandra 2019	+	-	+	-	!	-	D1 Randomisation process
Scott Lynn 2012	!	-	+	+	!	-	D2 Deviations from the intended interventions
Pabon-Carrasco Manuel 2020	+	!	+	+	-	-	D3 Missing outcome data
Iwona Sulowska-Daszyk 2020	!	+	+	+	!	!	D4 Measurement of the outcome
Pinar Kisacik 2021	+	+	+	-	!	-	D5 Selection of the reported result

Fig. 3. Risk of bias summary: a review of the authors’ evaluations concerning each risk of bias item for each included study.

### 3. Results

#### 3.1. Study selection

A database search identified 291 potential studies, and 211 abstracts remained after duplicate studies had been removed. The abstracts were then reviewed, and a preliminary evaluation was conducted to assess the eligibility of 21 full-text articles. Nine studies met our inclusion criteria and 12 were excluded, as the interventions in those studies were deemed inappropriate (Fig. 1).

#### 3.2. Study characteristics

##### 3.2.1. SFE setting

The basic characteristics of the nine selected studies

are shown in Tables 1 and 2. Concerning the number of times a single SFE intervention was conducted, the minimum was five times and the maximum was 104 times. Interventions were provided 2–7 days per week, and the intervention period ranged from 4–14 weeks. The total score ranged from 120 to 6552. One study did not provide details concerning the number of repetitions; therefore, the total score could not be calculated.

##### 3.2.2. The MLA

Navicular height, the navicular drop test (ND), and the FPI were used to measure the MLA. Six reports concerning the MLA were identified, of which four reported an improvement in the MLA. Kim et al. conducted a five-week SFE study among university students with flat feet and reported a significant decrease in ND post-intervention [33]. Okamura et al. conducted SFEs with electromyographic biofeedback in university students with flat feet and reported a significant post-intervention improvement in the FPI at eight

Table 1  
Characteristics of the selected studies

Author	Year	Patient	Number of patients	Group	Introduction practice	Intervention	Outcome for MLA	Outcome for conditions other than MLA
Jung et al.	2011	University students with flexible flat foot	28 M: NR F: NR	(1) FO + SFE (2) FO	FOSF group were also instructed in a short-foot exercise protocol.	(1) wear FO + SFE (2) wear FO	None	<ul style="list-style-type: none"> <li>- Cross-sectional area (CSA) of the abductor hallucis (AbdH) muscle</li> <li>- Strength of the flexor hallucis (FH)</li> </ul>
Fraser et al.	2017	Healthy adult	24 M: 12 F: 12	(1) intervention (2) control	All participants were verbally instructed, provided demonstration, and guided through a single practice trial of the toe-spread-out, hallux-extension, and lesser-toe-extension exercises prior to baseline assessment.	(1) SFE + Toe-spread-out Hallux-extension Lesser-toe-extension exercise. (2) No intervention	None	<ul style="list-style-type: none"> <li>- Clinician-assessed motor performance</li> <li>- Participant-perceived difficulty</li> <li>- USI motor activation measures of the abductor hallucis (AbdH), flexor digitorum brevis (FDB), quadratus plantae (QP), and flexor hallucis brevis (FHB)</li> </ul>
Iwona et al.	2020	Amateur runners	80 M: 57 F: 23	(1) SFE (2) control	NR	(1) SFE, Reverse Tandem Gait exercise Vele's Forward Lean Exercises with band loops strengthening Stability disc exercises (2) No intervention	None	<ul style="list-style-type: none"> <li>- Functional Movement Screen (FMS) test</li> <li>- Myofascial flexibility</li> </ul>
Kim et al.	2016	University students with flexible flat foot	14 M: 10 F: 4	(1) SFE (2) ASI	Before the intervention, the researcher demonstrated the short foot exercises while giving verbal instructions.	(1) SFE (2) Walking with ASI	ND	Y-balance tests
Kisack et al.	2021	Patients with PFP	30 M: 5 F: 25 drop out: 5	(1) SFE (2) control	NR	(1) SFE (2) Hip and knee strengthening and stretching exercises	ND FPI	<ul style="list-style-type: none"> <li>- Visual Analogue Scale</li> <li>- Kujala Patellofemoral Scale</li> <li>- Rearfoot angle</li> </ul>
Lynn et al.	2012	Healthy adult	24 M: 15 F: 15 drop out: 6	(1) SFE (2) TCE (3) control	The SFE and TCE groups were instructed to return to the laboratory 1 week after initial testing to receive training on exercises that were to be performed during the training phase of the study.	(1) SFE (2) TCE (3) No intervention	ND	<ul style="list-style-type: none"> <li>- Range of the mediolateral (ML) movement of the center of pressure (COP) during participants stood on 1 foot for 30 seconds,</li> <li>- Y balance test</li> </ul>

Table 1, continued

Author	Year	Patient	Number of patients	Group	Introduction practice	Intervention	Outcome for MLA	Outcome for conditions other than MLA
Okamura et al.	2020	University students with flexible flat foot	20 M: 3 F: 17	(1) SFE (2) control	Participants received verbal instruction and a demonstration of the correct technique to perform the short-foot exercise.	(1) SFE + EMG + ES (2) No intervention	ND FPI	<ul style="list-style-type: none"> <li>Foot kinematics during gait, including dynamic navicular drop – the difference between navicular height at heel strike and the minimum value – and the time at which navicular height reached its minimum value</li> <li>Thickness of the intrinsic and extrinsic foot muscles using ultrasound</li> </ul>
Manuel et al.	2020	University students with flexible flat foot	85 M: 42 F: 48 drop out: 5	(1) SFE (2) NBFEE	NR	(1) SFE (2) NBFEE	ND FPI	None
Ramachandra et al.	2019	Pregnant women	86 M: F: 86	(1) Study group (2) Control	NR	(1) Regular antenatal exercise + SFE, Heel raises raises Toe raises small object Toe curl Ankle inversion and eversion exercises Ankle circling exercises Calf muscle stretching (2) Regular antenatal exercise	Navicular height	<ul style="list-style-type: none"> <li>Foot length</li> <li>Foot width</li> </ul>

SFE: short foot exercise, ASI: ankle support insole, NR: not reported, EMG: electromyogram, ES: electrical stimulation, PFP: patellofemoral pain, TCE: toe curl exercise, NBFEE: non-biomechanical function exercise, FO: foot orthosis.

Table 2  
Total score of selected studies

Author	Year	Patient	Number of patients	Group	Introduction practice	Intervention	Total score	Period [week]	Number of exercise interventions/day or week	Time of intervention	Number of repetitions	Number of sets
Jung et al.	2011	University students with flexible flat foot	28 M: R F: NR	(1) FO + SFE (2) FO	FOSF group were also instructed in a short-foot exercise protocol.	(1) wear FO + SFE (2) wear FO	1680	8	(1) 2/day × 7 days/week (2) none	(1) NR (2) none	(1) 5 (2) none	(1) 3 (2) none
Fraser et al.	2017	Healthy adult	24 M: 12 F: 12	(1) intervention (2) control	All participants were verbally instructed, provided demonstration, and guided through a single practice trial of the toe-spread-out, hallux-extension, and lesser-toe-extension exercises prior to baseline assessment.	(1) SFE + Toe-spread-out Hallux-extension Lesser-toe-extension exercise, (2) No intervention	6552	4	(1) 3/day × 7 days/week (2) none	(1) NR (2) none	(1) 15 → 8 (2) 3 → 3 (2) none	(1) 3 (2) none
Iwona et al.	2020	Amateur runners	80 M: 57 F: 23	(1) SFE (2) control	NR	(1) SFE, Reverse Tandem Gait exercise Vele's Forward Lean Exercises with band loops strengthening Stability disc exercises (2) No intervention	1260	6	(1) 1/day × 7 day/week (2) none	(1) 30 minutes (2) none	(1) 30 (2) none	(1) 1 (2) none
Kim et al.	2016	University students with flexible flat foot	14 M: 10 F: 4	(1) SFE (2) ASI	Before the intervention, the researcher demonstrated the short foot exercises while giving verbal instructions.	(1) SFE (2) Walking with ASI	Not repetitions but time	5	(1) 1/day × 3 days/week (2) 1/day × 3 days/week	(1) 30 minutes (2) 30 minutes	(1) NR (2) NR	(1) 1 (2) 1

Table 2, continued

Author	Year	Patient	Number of patients	Group	Introduction practice	Intervention	Total score	Period [week]	Number of exercise interventions/day or week	Time of intervention	Number of repetitions	Number of sets
Kisacki et al.	2021	Patients with PFP	30 M: 5 F: 25 drop out: 5	(1) SFE (2) control	NR	(1) SFE (2) Hip and knee strengthening and stretching exercises	120	6	(1) 1/day × 2 days/week (2) 1/day × 2 days/week	(1) NR (2) NR	(1) 10 (2) 10	(1) 1 (2) 1
Lynn et al.	2012	Healthy adult	24 M: 15 F: 15 drop out: 6	(1) SFE (2) TCE (3) control	The SFE and TCE groups were instructed to return to the laboratory 1 week after initial testing to receive training on exercises that were to be performed during the training phase of the study.	(1) SFE (2) TCE (3) No intervention	2800	4	(1) 1/day × 7 day/week (2) 1/day × 7 days/week (3) none	(1) NR (2) NR (3) none	(1) 100 (2) 100 (3) none	(1) 1 (2) 1 (3) none
Okamura et al.	2020	University students with flexible flat foot	20 M: 3 F: 17	(1) SFE (2) control	Participants received verbal instruction and a demonstration of the correct technique to perform the short-foot exercise.	(1) SFE + EMG + ES (2) No intervention	720	8	(1) 1/day × 3 days/week (2) none	(1) 5 sec/time (2) none	(1) 10 (2) none	(1) 3 (2) none
Manuel et al.	2020	University students with flexible flat foot	85 M: 42 F: 48 drop out :5	(1) SFE (2) NBFPE	NR	(1) SFE (2) NBFPE	140	4	(1) 1/day × 7 day/week (2) 1/day × 7 days/week	(1) 30 sec/time (2) 30 sec/time	(1) 5 (2) 5	(1) 1 (2) 1



Table 2, continued

Author	Year	Patient	Number of patients	Group	Introduction practice	Intervention	Total score	Period [week]	Number of exercise interventions/day or week	Time of intervention	Number of repetitions	Number of sets
Ramachandra et al.	2019	Pregnant women	86 M: 0 F: 86	(1) Study group (2) Control	NR	(1) Regular antenatal exercise + SFE, Heel raise, Big toe raises Toe raises Picking up small object Toe curl Ankle inversion and eversion exercises Ankle circling exercises Calf muscle stretching (2) Regular antenatal exercise	4320	14	(1) 1/day × 4 days/week (2) none	(1) NR (2) NR	(1) 20 (each) → 30 (2) none	(1) 3 (2) NR

SFE: short foot exercise, ASI: ankle support insole, NR: not reported, EMG: electromyogram, ES: electrical stimulation, PFP: patellofemoral pain, TCE: toe curl exercise, NBFE: non-biomechanical function exercise, FO: foot orthosis.

weeks [26]. Ramachandra et al. conducted 14 weeks of SFEs in pregnant women and reported a significant post-intervention increase in navicular height [34]. Kısacık et al. conducted a six-week SFE study of patients with patellofemoral pain (PFP) and reported a significant decrease in ND and FPI scores post-intervention [35].

### 3.2.3. Other outcomes

The outcomes for conditions other than the MLA were IFM function and morphology, balance, foot morphology, and the dynamic navicular drop (DND) test. In three studies, IFM function and morphology were used as outcomes, and both IFM thickness and muscle activity were reported to have improved [23,26,36]. Of two studies that used balance as an outcome, all patients showed an improvement in dynamic balance [33,38]. One study used foot morphology as an outcome in pregnant women and reported that foot length and width increased with advancing gestational weeks in the control group, but foot length and width did not change with advancing gestational weeks in the SFE group [34]. One study used the DND test as an outcome, and reported no change in DND test results [26]. Another study used a visual analogue scale and the Kujala patellofemoral scale as outcomes in patients with PFP, and reported that values in both scales reduced post-intervention [35]. However, another study used functional movement screen test results as a study outcome and reported that scores increased post-intervention [37].

### 3.2.4. Risk of bias

Figures 2 and 3 show risk of bias ratings for each included study. All studies had an increased risk due to the impossibility of blinding the participants. The risk of bias was also increased for studies that did not describe the randomization process, deviations from the intended intervention, missing outcomes, outcome measures, or selection of outcomes to report.

## 4. Discussion

### 4.1. Summary

A systematic review of the number and frequency of SFEs, the duration of the intervention, and the types of outcomes, was undertaken to determine the effects of SFEs. Four studies showed MLA improvement compared with two studies that showed no improvement in the MLA. For outcomes other than the MLA, IFM

function and morphology, balance, foot morphology, and DND tests were used, showing the effect of SFEs on IFM thickness and activity, and improvement in balance.

### 4.2. Effects of the intervention on the MLA

Recently, several systematic reviews have focused on IFMs. Willems et al. examined the effects of a plantar IFM strengthening intervention on dynamic balance control and foot function during gait in adults [38] and Erin et al. reported the effects of an intervention on functional mobility [39]; however, neither intervention method was limited to performing SFEs. In a systematic review, Cameron et al. focused on SFEs but limited their investigation to ND as the outcome [40]. Our study provided a review of studies reporting the effectiveness, frequency, and duration of SFE interventions.

Four of six included studies found improvement in the MLA with SFEs. MLA improvement was observed for interventions of  $\geq 5$  weeks duration [26,33–35]; however, no improvement was observed for interventions of  $< 5$  weeks duration [41,42]. The total scores were 720 and 4320 for the studies in which the MLA improved. In one study, the total score could not be calculated because the number of repetitions was not stated. The score for the study without improvement was 2800. This result suggests that the amount of SFE load may not affect improvement of the MLA. Although we could not reach a consensus concerning the number or frequency of SFEs on MLA improvement, our findings suggest that SFEs should continue for  $> 5$  weeks.

The plantar fascia is reported to be a major contributor to MLA retention [43–45]. The plantar fascia overlaps the IFMs and attaches to the flexor digitorum brevis. Therefore, IFM strengthening plays an important role in maintaining the foot's medial longitudinal arch [21,46]. Three studies described the use of IFM function and morphology as study outcomes and reported improvements in both muscle thickness and muscle activity. However, no study reported changes to the structure of the IFM in relation to the height of the MLA. Furthermore, one study reported no significant change in IFM thickness but improvement in the MLA [26]. Additionally, one study showed an increase in the muscle cross-sectional area of the abductor hallucis muscle, but no change to navicular height [47]. That study did not find an association between IFM hypertrophy and the MLA. Therefore, the effect of SFEs on the MLA require further investigation of morphological changes from an IFM perspective as well as from multiple other perspectives.

### 4.3. Effects on balance

Two studies showed an improvement in balance function [33,41]. Kim et al. used the Y-balance test as an outcome measure of balance [33]. Lynn et al. used a force plate and found a decrease in center of pressure movements during the Y-balance test [44]. It has been reported that patients with flat feet are more unstable in a static standing position than those without flat feet [48] and, in a study that evaluated dynamic stability during closed-eye standing using a force plate, participants with flat feet were reported to have significantly lower dynamic stability than those with normally arched feet [49]. Lee et al. reported that eight weeks of SFE intervention improved joint position, sense of the ankle joint, and dynamic balance in patients after ankle sprain [50]. In a systematic review of balance training, the most effective intervention period for improving balance ability was 11–12 weeks, and many reports indicate interventions of 5 weeks or longer [51]. From these reports, a period of more than 5 weeks is required for the prompting of the proprioceptive sensation, which is consistent with the period required for the improvement of MLA by SFE. In other words, SFE may have stimulated proprioceptive sensation in the foot, leading to an improvement in MLA. However, none of the RCTs selected in this study targeted proprioceptive sensation. We hypothesized that SFE had an influence with central nervous systems factors that affect muscle strength is the change in the firing rate of alpha motor neurons (rate coding). When the CNS instructs a muscle to contract, both alpha and gamma motor neurons are activated. Gamma motor neurons to contract the intrafusal fibers appropriately. Thus, IFM with SFE altered the firing rate of gamma motor neurons, resulting in altered proprioception.

### 4.4. Clinical significance of Neues

Five weeks of continuous SFE for flat feet may improve morphology and proprioception in the IFMs and improve the MLA. In addition, SFEs have been shown to be more effective than functional orthotic therapy in improving the MLA [33].

### 4.5. Study limitations

This study had several limitations. First, we did not perform a meta-analysis of three studies that reported efficacy in improving the MLA because those studies included a wide range of participants, such as pregnant

women, patients with PFP, and college students. Second, it was not possible to determine whether the participants were able to learn how to correctly perform the SFEs. In previous studies, SFE requires an hour to two weeks of practice to master, and there are reports of failure to master this exercise even after practice [29]. One included study explained how to perform the SFE but did not mention the time taken to practice or an assessment of whether it had been performed correctly. Okamura et al. used electromyography as feedback, whereas no feedback was provided in other studies [26].

## 5. Conclusions

The results of this study suggested that SFEs were effective in improving the MLA in participants with flat feet with an intervention period of > 5 weeks. The number and frequency of SFEs were not uniform across the studies, and the mechanism of MLA improvement was not clear. The effect of the balancing function on MLA improvement was also unclear. Future RCTs investigating changes in the MLA in relation to IFM morphology and proprioception are required.

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## Conflict of interest

The authors have no conflicts of interest to declare.

## Ethical approval

No individual patient data was used for the meta-analysis. Ethical approval was thus not required.

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