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Short-Foot Exercise Promotes Quantitative Somatosensory Function in Ankle Instability: A Randomized Controlled Trial

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Data Collection B
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Data Interpretation D
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Literature Search F
Funds Collection G

BCEF 1 **Eunsang Lee**
BF 1 **Juchul Cho**
AD 2 **Seungwon Lee**

1 Department of Physical Therapy, Graduate School of Sahmyook University, Seoul, South Korea
2 Department of Physical Therapy, College of Health and Welfare, Sahmyook University, Seoul, South Korea

Corresponding Author: Seungwon Lee, e-mail: swlee@syu.ac.kr

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Background: Ankle sprain reduces capacity for neurosensory information processing, and these patients commonly progress to chronic ankle instability (CAI). To address this problem, the short-foot exercise (SFE) may be used. However, there has been no previous research on the neurosensory impact of SFE.

Therefore, the aim of this study was to assess improvement of quantitative neurosensory indicators after SFE and to determine the effect of proprioceptive sensory exercise (PSE) in patients with CAI.





Material/Methods: The present study included 30 adults (age range: 19–29 years; 50% female). Selection criteria for CAI (Cumberland Ankle Instability Tool ≤ 24) were implemented, and participants were randomly allocated to 2 groups: SFE ($n_1=15$) and PSE ($n_2=15$). Exercises were conducted 3 times per week for 8 weeks. Measurements of quantitative somatosensory of joint position sense and vibration sensory thresholds, dynamic balance, and ankle instability assessment were evaluated before and after completion of each intervention. Data were analyzed using a repeated-measures analysis of variance.

Results: In a time-by-group comparison, the SFE group showed a more significant improvement with regards to eversion joint position sense ($F_{1,28}=4.543, p<0.05$). For vibration sensory threshold, the SFE group showed a more significant improvement ($F_{1,28}=8.280, p<0.01$). Balance index according to antero-posterior, mediolateral, and overall index the SFE group a more significant improvement ($F_{1,28}=6.666, 4.585, 5.207, p<0.05$). And ankle instability SFE group showed a more significant improvement ($F_{1,28}=6.890, p<0.05$).

Conclusions: SFE is more effective than PSE for treating ankle sprain patients. There is a need to develop and promote an effective and controlled exercise program to facilitate the return of ankle sprain patients to normal daily life.

MeSH Keywords: **Ankle Injuries • Postural Balance • Proprioception • Somatosensory Disorders**

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Background

Physical inactivity is a major risk factor for morbidity and mortality [1], as well as having a negative social impact, including increases in healthcare costs and lowered participation in the workforce [2,3]. In an effort to reduce the risks associated with inactivity, individuals are increasingly participating in physical activities of sports and leisure [4,5]. This increased participation in physical activities, however, does increase an individual's risk for injuries. Lambers, Ootes, and Ring [6] reported sprains and strains to be the most common sports-related injury, accounting for 36% of all sports injuries, with the ankle joint being the most common site of injury (72%). McCriskin et al. [7] estimated that 2 million individuals sustain an ankle injury per year in the United States, with the cost of treating these injuries being an important healthcare concern [8].

Most ankle sprains initially cause pain and swelling, accompanied by joint kinematic problems. Moreover, various musculoskeletal syndromes of the lower extremity can develop secondary to the effects of ankle injuries in decreasing proprioception. These secondary syndromes include plantar fasciitis [9,10], iliotibial band syndrome [11], patellofemoral pain syndrome [12], patellar tendinitis [13], medial tibial stress syndrome, and medial knee pain [11]. Additionally, 70–80% of patients who sustain an ankle sprain develop chronic ankle instability (CAI) [14], which is a predisposing factor for repetitive ankle injury [15,16].

Ankle sprains are also often associated with neurological and mechanical impairments. Deficits in somatosensory function have been associated with decreases in ankle strength and coordination, which can lead to ankle instability [17]. Somatosensory function, which includes proprioception, is defined as the wide-ranging sensory information arising from joint receptors (joint capsules and ligaments) and from muscle and cutaneous mechanoreceptors [18], which is used for the control of posture and movement [19]. Ankle proprioception is essential for performing functional activities that require standing balance [20] and to maintain overall posture [18]. Consequently, researchers and clinicians have focused on enhancing ankle proprioception and postural stability through the use of balance and coordination training programs for the prevention of recurrent ankle sprains [8,21–23].

Short-foot exercise (SFE) is a widely used balance training intervention that has been developed recently to improve ankle proprioception and to strengthen the intrinsic foot muscles (IFM) so as to elevate and support the medial longitudinal arch (MLA) of the foot and improve dynamic standing balance [24]. SFE is performed by attempting to pull the head of the first metatarsal toward the calcaneus, without curling the toes [25]. Lynn, Padilla, and Tsang [26] reported a decrease in the lateral displacement of the center of pressure

(CoP) during a dynamic balance test following a 4-week program of SFE training. However, the efficacy of SFE training in enhancing the proprioceptive function of the ankle joint has not yet been evaluated against that of conventional proprioception exercises (PSE) and balance training [24]. Therefore, our aim in this study was to compare the effectiveness of SFE and PSE within the context of rehabilitation of ankle sprains.

Material and Methods

Our study was performed using a randomized controlled design with blinded evaluators. Clinical assessments of somatosensory function, dynamic balance, and ankle instability were performed to obtain baseline values of ankle function. Following this initial assessment, participants were randomly allocated to either the SFE or PSE group. Exercises in both groups were performed 3 times a week for 8 consecutive weeks. Clinical assessments were re-evaluated at the end of the 8-week program. The study protocol was approved by the Institute Review Board of the University (SYUIRB2014-118). Flow diagram in Figure 1 shows the flow of participants through the trial.

Participants

Participants were recruited from among university students, using the following inclusion criteria: (1) history of a first ankle sprain more than 1 year prior to the trial; (2) a score of less than 24 on the Cumberland Ankle Instability Tool (CAIT); (3) no incidence of ankle sprain within 6 weeks of the start of the trial; and (4) experienced at least 2 more ankle sprains in the past 1 month. Participants were also screened on the following exclusion criteria: (1) history of lower-extremity surgery; (2) therapy of the affected lower extremity within the previous month; and (3) psychiatric disorders. An initial group of 73 participants was recruited. From this group, those with CAI were identified. A cutoff score of less than 24 on the CAIT was used to match participants with a similar level of CAI, as per previously published methods [27,28]. Sample size determination was based on the data of Lynn et al. [26], which reported a large effect size of SFE (Cohen's d , 0.80). The data were transformed to meet the assumptions for repeated measures, with an effect size $f(V)$ of 0.4, and the sample size calculated using G-power (version 3.1; Franz Faul, Universität Kiel, Germany). For an $f(V)$ of 0.4, with an α error probability level of 0.05 and a power ($1-\beta$ error probability) of 0.80 and considering 2 time points of measurement for each of the 2 groups, a sample size of 24 participants would be needed. Assuming a 20% attrition rate, a total of 30 subjects were ultimately selected for the trial [29]. Random Allocation Software (version 2.0) was used to allocate the 30 participants to each of the 2 study groups, using blocs of 4, and ensuring an equal gender

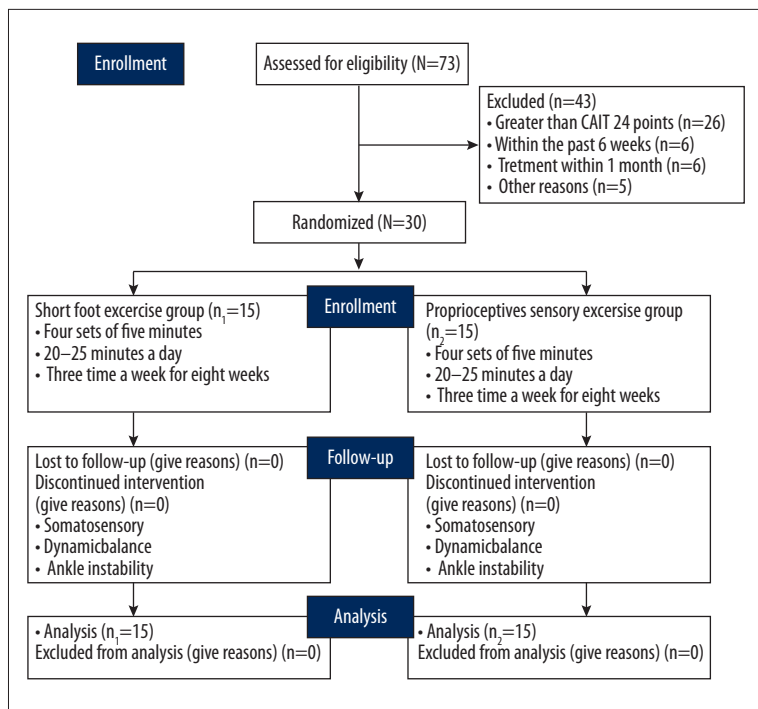


Figure 1. Flow of participants: Short-foot exercise versus a proprioceptive sensory exercise. Patient-Specific Functional Scale; CAIT – Cumberland ankle instability tool.

distribution between the 2 groups, based on previously published methods [30].

Intervention

Short-foot exercise program

SFEs were performed according to the methods of Prentice and Kaminski [31]. Participants were instructed to shorten their foot in the anterior-posterior direction, while actively attempting to bring the head of the first metatarsal toward the heel without curling the toes (Figure 2). To provide adequate floor friction and to avoid slipping during the performance of the SFE, a stability trainer (Thera-Band, USA, blue) was used. According to the principle of progressive overload, the intensity of exercise was divided into 2 levels. For weeks 1–4, the SFE was performed in a sitting position and subsequently performed in standing for weeks 5–8. Performance of the SFE in the sitting position was based on previously published methods, as follows: seated position with both feet on the stability trainer, with the hips, knees and ankle at 90° of flexion to stabilize the body [32]. For weeks 5–9, the SFE was performed in the single-leg stance on the stability trainer to provide body-weight resistance. In both seated and standing positions, the SFE was held for 5 s, with 12 repetitions forming 1 block, and 3 blocks completed per training session, with a 2-min rest period between blocks. Three sets were performed 3 times a week.

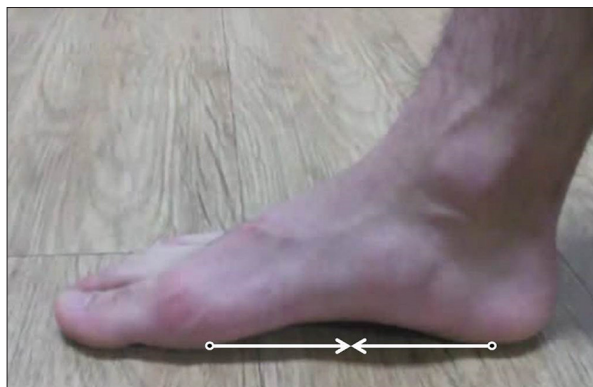


Figure 2. Short-foot exercise.

Proprioceptive sensory exercise

PSEs were performed according to the methods of Jain, Wauneka, and Liu [33] and Dean, Richards, and Malouin [34], with care to match the intensity level to that for SFEs. During weeks 1–2, the PSE was performed on a stable floor, and the on an Airostep (TOGU, USA) during weeks 3–5 and on a Posturomed (Haider Bioswing, Germany) during weeks 6–8. PSEs were consistently performed with the eyes open, in the single-leg stance, with the affected side on the different support surfaces, and the uninvolved contralateral leg flexed at 90° at the ankle, with both arms held out horizontally. Participants maintained the position for 30 s, followed by a 10-s rest, with 4 repetitions completed. Each set was repeated 3 times a week.



Figure 3. Measurement of Joint Position Sense on Ankle (Biodex system 4pro, Biodex medical systems, Inc., USA).

A total of 24 sets of SFE and PSE were completed over the 8-week intervention program.

Outcome measures

Somatosensory

Somatosensory function was quantified using both proprioceptive (joint position) sense and threshold of vibration sense, as per the methods of Tibone et al. [35], to increase the reliability of measurement. Joint position sense was measured using the Biodex system 4pro (Biodex Medical Systems, Inc., USA), according to the methods of Saha et al. [36]. The assessment was conducted in a quiet room with participants blindfolded to eliminate visual and auditory cueing. Participants were thoroughly informed of the testing procedure prior to the assessment.

The test was performed with shoes on, with the foot attached to the measuring plate and the ankle aligned with the center of rotation of the Biodex, ensuring that the lateral epicondyle of the femur and the movement axis were aligned in a

straight line. Participants were restrained across the chest and at the shoulder, pelvis, and thighs using straps. Prior to the assessment, the maximum end-point of inversion and eversion were measured to set the range of motion. The measurement plate was then held at the ankle's initial angle for 5 s and at the end-point angle for another 5 s. Participants were then asked to reproduce the target angle and to push the stop button when they believed the target angle had been obtained. For all participants, joint position sense was first measured in eversion and then in inversion after a 30-s rest period. The target angle was set at 15° for both eversion and inversion. Measurements were repeated 3 times, with the average difference between the self-determine and target end position calculated according to the methods of Tankevicius et al. [37]. A smaller difference indicates better the joint position sense of the ankle (Figure 3). Tankevicius et al. [37] reported that this assessment of ankle joint position sense has high reliability, with a 95% confidence interval of intra-class correlation (ICC) scores of 0.87–0.96.

The threshold of vibration was assessed using a Neurosensory Analyzer-II (Vibratory Sensory Analyzer-II, MEDOC, Inc., Ramat, Israel) according to the methods of Blankenburg et al. [38]. The device was initially connected to the feet and hands for calibration to a fixed value (Figure 4). Based on previous research, the medial malleolus of the affected ankle was selected for measurement according to the method described by Goble et al. [39]. For quantitative analysis of vibration threshold, a vibration sensor (12-mm diameter) was placed perpendicular to the long axis of the medial malleolus. For stimulation, the platform's internal 50-g control pressure was used (Figure 4A). A vibration of 100 Hz was delivered at a rate of 1 $\mu\text{m/s}$, which was gradually increased until participants detected the vibration. A vibration range of 0.1–130.0 $\mu\text{m/s}$ was used, and participants pushed either the 1/Y (sensation detected) or 2/Y (no sensation) button, as appropriate (Figure 4B). The test was repeated 6 times and the average detection threshold was calculated. A lower detection threshold indicates a better

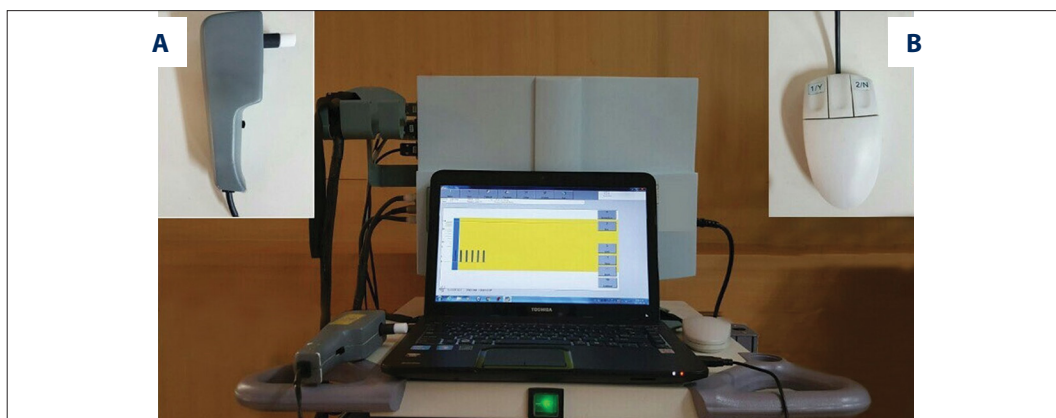


Figure 4. (A, B) Neurosensory analyser-II (Vibratory sensory analyser-II, MEDOC, Inc., Ramat Israel).

Table 1. Demographic characteristics of the subjects (N=30).

	SFEG (n ₁ =15)	TCEG (n ₂ =15)	t/ χ^2 (p)
Age (year)	21.53±2.47*	22.00±2.70	-0.494 (0.625)
Gender (Male/Female)	7/8	8/7	0.133 (0.715)
Affect side (left/right)	7/8	6/9	0.136 (0.713)
Height (cm)	168.72±9.86	165.28±8.75	1.008 (0.322)
Weight (kg)	64.21±13.68	61.34±9.56	0.602 (0.511)
Shoes size (mm)	249.00±19.01	248.33±16.87	0.102 (0.920)
Onset time (week)	8.33±2.23	8.60±2.77	-0.291 (0.774)

Values are presented as mean ±SD. SFEG – short foot exercise group; PSEG – proprioceptive sensory exercise group.

vibration sense. The device and methods used are considered to be the criterion standard for threshold of vibration detection, with ICC values of 0.96–0.99 [40].

Dynamic balance

Dynamic balance was measured using the Biodex balance system SD (BBS, Biodex, Inc., USA), and its associated postural stability program, with the power plate used to detect the longitudinal and lateral motions connected to a computer for the calculation of the balance index using Biodex software (Biodex 950-302, Biodex, Inc., USA). Tests were performed without shoes. Using the program's internally-generated sequences, participants were asked to resist the movements of the platform and maintain their standing balance. Dynamic balance was measured for levels 6 to 2 of the program, with the intensity of platform displacement increasing as the levels decreased. Visual feedback on the center of gravity was provided for all trials. The displacement in the position of the center of gravity was used for calculation of balance index, with index scores ranging from '0' (the highest stability score) to '9' (the highest instability score) [41]. The following components of dynamic balance were calculated: overall balance index (OBI), antero-posterior balance index (ABI), and medio-lateral balance index (MBI). The test-retest reliability for these indices have been previously reported Cachepe et al. [42]: $r=0.94$ (OBI), $r=0.95$ (ABI), and $r=0.93$ (MBI), indicative of high reliability.

Ankle instability

The CAIT, which we used in our study, is a validated and reliable instrument to identify ankle instability and risk of recurrent ankle sprains, with a sensitivity of 82.9% and specificity of 74.7% [27]. As suggested by the International Ankle Consortium [28], an ankle instability cutoff score of 24 points was used to classify patients with and without a CAI. The CAIT consists of 9 questions, with 5 questions answered on a scale of 3–0, 2 questions on a scale of 4–0, 1 question on a scale of 5–0, and the last question on a scale of 2–0. Based on the

highest possible score of 30, scores exceeding 28 points are indicative of a stable ankle and scores ≤ 24 points indicative of ankle instability [43].

Data analysis

All statistical analyses, including calculation of the mean and standard deviation, were performed using SPSS statistical software (version 21.0 for windows; SPSS, Inc., Chicago, USA). The normality of distribution for quantitative data was assessed using the Kolmogorov-Smirnov test ($p>0.05$). Between-group differences in baseline data were evaluated to assess the homogeneity of the randomization, with independent t tests used for continuous data and chi-square test for independence for nominal data. The effects of treatment on somatosensory perception, dynamic balance, and ankle instability were evaluated using a repeated-measures analysis of variance (ANOVA), with treatment group (SFE vs. PSE) as the between-subject variable and time (Baseline and Follow-up) as the within-subject variable. To examine the effect size of the treatment, the partial Eta squared (η^2) was calculated. Statistical significance was set at an α of 0.05 for all analyses.

Results

Among the initial group of 73 individuals with a past history of ankle sprains, 37 were excluded as follows: 26 individuals with a CAIT score >24 points, 6 individuals who had sustained an acute ankle sprain within the previous 6 weeks, and 5 other individuals who did not meet the inclusion criteria for other reasons. Therefore, our study group was formed of 30 men and women with CAI, with a mean (\pm standard deviation) age of 21.77±2.56 (range, 20–29) years, with the right ankle involved in 43% of cases and the left ankle in 57%. The mean time from the onset of CAI symptoms to testing was 9.47±2.47 (range, 7–17) weeks. All participants provided informed consent. The descriptive statistics of our study group are presented in Table 1.

Table 2. Differences in short foot exercise group and proprioceptive sensory exercise (N=30).

	SFEG (n ₁ =15)		PSEG (n ₂ =15)		Time×Group		η_p^2
	Baseline	Follow-up	Baseline	Follow-up	F[95% CI]		
Somatosensory							
Joint position sense (eversion, deg)	3.95±1.55	1.59±.96	3.65±1.46	2.15±1.22	4.543	(1.474–2.106)*	0.140
Joint position sense (inversion, deg)	2.66±0.72	1.87±0.76	2.78±0.79	2.23±0.78	0.705	(0.686–1.198)	0.025
Vibration threshold sense (µm)	4.29±.98	2.50±.79	3.73±1.14	2.87±1.24	8.280	(0.908–1.466)**	0.227
Dynamic balance							
OBI (Cm)	4.27±1.58	2.15±.85	3.62±1.36	2.57±.99	6.666	(1.767–1.372)*	0.192
MBI (Cm)	3.35±1.01	1.49±.82	2.74±1.53	1.68±1.13	4.585	(1.029–1.644)*	0.141
ABI (Cm)	3.11±1.05	1.41±.67	3.03±1.14	2.03±1.13	5.207	(0.969–1.493)*	0.157
Ankle instability							
CAIT (point)	21.07±1.44	26.40±2.06	21.13±1.81	24.57±1.52	6.890	(3.711–4.756)*	0.197

Values are presented as mean ±SD. SFEG – short foot exercise group; PSEG – proprioceptive sensory exercise group; OBI – overall balance index; MBI – mediolateral balance index; ABI – anteroposterior balance index; CAIT – Cumberland Ankle Instability Tool; CI – Confidence interval; * p<0.05, ** p<0.01.

A significant between-group difference in position sense in eversion was identified, with 2.36° error (59%) for the SFE group compared to the 1.5° (41%) for the PSE group, and a η_p^2 of 0.14, indicative of a large group effect. Similar to inversion, the error in position of 1.12° (29%) for the SFE group was greater than the error of 0.56° (18%) for the PSE group, with the η_p^2 was 0.113 indicative of a medium group effect. The vibration sense threshold decreased by 1.75 µm/s (42%) for the SFE group, compared to 0.86 µm/s (23%) for the PSE group, and a η_p^2 of 0.228, indicative of a large group effect (Table 2).

With regard to dynamic balance, the OBI decreased by 2.12 cm (49%) in the SFE group compared to 1.05 cm (29%) for the PSE group, and a η_p^2 of 0.192, indicative of a large group effect. Similarly, a significant between-group difference in the MBI and ABI components of dynamic stability was identified, as follows: the MBI decreased by 1.86 cm (56%) for the SFE group and 1.06 cm (39%) for the PSE group, and a η_p^2 of 0.141, indicative of a large group effect; the ABI decreased by 1.70 cm (55%) for the SFE group, compared to 1.0 cm (33%) for the PSE group, and a η_p^2 of 0.15, indicative of a large group effect (Table 2).

With regard to ankle stability, the CAIT score increased by 5.33 points (20%) in the SFE group compared to an increase of 3.44 points (14%) for the PSE group, and a η_p^2 of 0.19, indicative of a large group effect (Table 2).

Discussion

Ankle sprains have a high rate of recurrence, with the resulting ankle instability increasing the risk for secondary musculoskeletal syndromes of the lower limb due to reduced ankle proprioception [16]. Muscle receptors contribute significantly to ankle proprioception, providing sensory feedback on changes in muscle length and joint position and velocity of movement. This information is used by the central nervous system for movement planning and execution [39]. Based on the premise that CAI develops due to reduced proprioception and eversion strength of the ankle following an acute sprain, Docherty and Arnold [44] argued that proprioceptive sensory training should be considered as an essential component of the rehabilitation of patients following an ankle injury. Zang et al. [45] argued that deficits in ankle proprioception could impair the functional stability of the ankle joint, as well as playing a role in impairment of the somatosensory control of balance. For these reasons, we sought to evaluate the relative efficacy of SFE and PSE in improving the sensory function of the ankle in patients with CAI.

Our results identified a benefit of SFE over PSE in improving position sense of the ankle in eversion (p=0.042), but we found no effect of exercise type on position sense in inversion (p=0.069). A benefit of SFE over PSE was also identified on recovery of the vibration threshold sense (p=0.008). According to Rothermel et al. [46], SFE improves neuromuscular activity.

Janda and Vavrova [47] proposed that SFE should be included early in proprioceptive re-training following an ankle injury, as it stimulates the neurocircuitry in the sole of the foot, which improves postural and core stability. Based on the idea that foot strength influences somatosensory control of standing posture and balance via its effects on muscle and tendinous receptors of the foot and ankle, including the plantar cutaneous receptors [48], McKeon et al. [49] introduced the 'foot core system', which links IFM strength to core stability, proposing that an abdominal drawing-in maneuver, which is a fundamental core stability training maneuver, be combined to the SFE to increase overall stabilization of the lower body. This proposed 'foot core system' is indirectly supported by Favejee et al. [50], who reported that a 12-week program of core stabilization exercises significantly reduced exercise-induced fatigue ($p=0.001$), which could improve lower-limb proprioceptive function. Skinner et al. [51] demonstrated that exercise-induced fatigue increased the error in proprioceptive information at the knee joint ($p<0.05$), with the magnitude of error on a joint position reproducing task at the knee being significantly correlated to the level of fatigue ($p<0.05$). Lattanzio et al. [52] estimated a 1° change in joint position sense with each increase in the level of Borg fatigue scale ($p<0.01$). Hiemstra et al. [53] similarly reported a decrease in joint position sense of the knee following repeated contractions of knee flexion and extension. Therefore, there is evidence that a stable core reduces muscular fatigue and, as a result, can improve lower-limb proprioception. It is therefore likely that the SFE program in our study improved the foot core strength linkage, reducing muscle fatigue of the lower limb and improving the proprioceptive function of the ankle. It is important to note that Soysa et al. [54] proposed an alternate possibility that SFE increases the strength of the IFM and thereby supports the arches of the foot, which would improve the alignment of the lower extremity and consequently the proprioceptive function of the lower extremity joints through a muscle-stretch response [47].

Mechanical effects of ankle sprains have also been reported. Ankle sprains typically lead to a pronated position of the foot, with the resulting lowering in the position of the navicular being associated with a risk of impingement of the tibial nerve and a resultant decrease in sensation over the medial malleolus [55]. SFEs can correct the position of the navicular bone in these cases, with increased IFM strength raising the MLA and thus the height of the navicular, and improving sensory function of the ankle [48]. Fiolkowski et al. [55] reported a 3-mm increase in navicular height and improved sensory conduction of the tibial nerve after IFM strengthening in patients who had sustained an ankle sprain ($p<0.05$). The sensory contribution of the tibial nerve contributes significantly to the ankle joint position sense, as well as to the motor control of the ankle via activation of the tibialis posterior, flexor digitorum longus, and the flexor hallucis longus muscles [56].

The absence of a group effect on the ankle joint position sense in inversion in our study ($p=0.408$) is likely explained by the mechanism of injury of ankle sprains. Ankle sprains are typically inversion injuries (85% of all ankle sprains) caused by internal rotation and adduction of the lower limb over a foot in fixed plantar flexion position [57]. Inversion injuries cause damage to the lateral complex of the ankle, including injury to the tibio-fibular ligament (ATFL) in 65% of cases, combined with injury to the calcaneo-fibular ligament in 20% of cases [57]. For this reason, the structures on the medial aspect of the foot and ankle are rarely damaged; therefore, decreases in position sense in inversion are not anticipated.

Importantly, there was significant improvement of the 3 components of dynamic balance (OBI, MBI, and ABI, $p\leq 0.04$) with SFE. Gimmon et al. [58] reported an increase in anterior-posterior and medial-lateral sway with increasing fatigue of the IFMs ($p=0.011$). This association between dynamic balance and IFM fatigue is likely mediated by the effects of IFM fatigue on the support of the arches of the foot and overall stabilization of the lower leg. Fatigue of the IFMs causes a lowering of the arches of the foot, with a resultant medial shift in the position of the center of pressure, which decreases balance control. This hypothesis is supported by Moon et al. [24], who reported a significant improvement in the limit of anterior-posterior and medial-lateral stability in 4 of 18 patients with a pronated foot after a program of SFE ($p<0.05$). Similarly, Lynn et al. [26] reported an improvement in anterior-posterior and medial-lateral control of the CoP of the dominant lower extremity following a 4-week program of either towel curl exercise (TCE) or SFE, performed 100 times per day ($p=0.02$). These studies support our finding of a positive effect of SFE, and the resultant increase in IFM strength, on dynamic balance. Lynn et al. [26] reported greater benefits of SFE over TCE. Therefore, we consider SFE to be a superior training method to increase the height of the MLA and contributing to increased stabilization of the COP.

The indices of dynamic stability (OBI, MBI, and ABI), however, improved to a greater extent with the program of PSE than SFE. Considering the benefits of increased IFM strength on balance, future research should assess whether combining SFE and PSE can enhance improvements in dynamic balance control, providing a new direction for balance training following an ankle injury.

O'Driscoll et al. [59] reported an improvement in CAIT score following neuromuscular training and Lee et al. [60] reported a significant increase in CAIT score ($p<0.05$) with SFE training. The balance deficits in CAI have been attributed to dysfunction of the common peroneal nerve, with a decrease in the reaction time of the peroneal muscles [61], and deficits in ankle proprioception [62]. In the present study we found SFE was superior to PSE in improving CAIT scores and, likely, the strength and proprioceptive deficits that are associated with CAI ($p=0.014$).

Conclusions

SFE training significantly improves proprioception and dynamic balance in patients with CAI who have experienced recurrent

ankle sprains, and it was more effective than PSE training. Inclusion of SFEs could accelerate recovery from ankle sprains and prevent the development of CAI, as well as facilitating a faster return to activities of everyday life and sports.

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