Research Article

Investigating the Effects of Intrinsic Foot Muscle Exercises on Dynamic Balance after Sub-Acute Ankle Sprain

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ABSTRACT

Introduction: This study compares the efficacy of routine treatment plus short foot exercises (SFE) with routine treatment alone on dynamic balance and pain in subjects with sub-acute ankle sprain.

Materials and Methods: A total of 32 patients (18-45 years old) with primary ankle sprain were randomly enrolled into the control group performing routine treatment alone or the SFE group performing routine treatment plus SFE. The dynamic balance was assessed using the star excursion balance test. Pain and ankle dorsiflexion range of motion were assessed using the numeric pain rating scale and a goniometer. The outcomes were evaluated at the baseline and after the end of treatment. The groups were compared using the one-way analysis of variance/analysis of covariance test. The effect sizes also were calculated to determine the efficacy of the SFE.

Results: Dynamic balance in the SFE group had a significant increase in the anterior, lateral, medial, and anteromedial directions compared to the control group (P=0.001, P=0.002, P=0.014, P=0.0001). No significant differences were observed between the groups in other directions of the star excursion balance test (P>0.05). Additionally, pain intensity was lower significantly in the SFE group than in the control group (P=0.0001). In the SFE group ankle dorsiflexion range was significantly more than the control group (P=0.025). The effect sizes also showed a high efficacy favoring SFE.

Conclusion: The combination of routine treatment and SFE can be an effective intervention for managing ankle sprain.

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Introduction

Sprain of the external ligaments of the ankle is one of the most common musculoskeletal disorders in athletes and active people [1, 2]. An ankle sprain is associated with increased pain while walking, burning sensation, discoloration, and bruising. The severity of these symptoms depends on the severity of the injury. Recurrence of ankle sprain is associated with pain, swelling, muscle weakness, giving way, and ankle instability [3-5].

The incidence of ankle instability is common after repeated ankle sprains [3]. Instability is either mechanical or functional [6, 7]. People who have functional instability frequently experience giving way, while mechanical instability leads to hypomobility or hypermobility of the ankle [4, 8]. Ankle instability limits physical activities and increases the incidence of ankle osteoarthritis [7, 9]. A wide range of interventions has been proposed to repair structures and restore function in ankle sprains [10-12]. Therapeutic exercise aimed at improving proprioception is considered as an essential component in the rehabilitation of ankle injuries [10, 13]. Impaired ankle proprioception can impair functional stability [11, 13]. For this reason, studies emphasize improving proprioception using coordination and balance training programs to prevent the recurrence of ankle sprains [14, 15].

One of the main challenges after an external ankle sprain injury is the possibility of re-injury [16], so reducing the risk of re-injury and ultimately chronic ankle instability is a key priority in lateral ankle sprain injury [16]. Short foot exercises (SFE) are widely used strengthening exercises of the intrinsic foot muscles, which aim to improve the proprioception of the ankle. These exercises are done by trying to pull the heads of the metatarsal bones toward the calcaneus without flexing the toes and lifting the forefoot and the heel off the ground [17]. These exercises are used as the first step in sensorimotor therapy and can be effective in improving proprioception [18].

The review of studies shows that intrinsic muscle exercises, especially SFE are widely used to improve proprioception and balance [17-19]. Ankle sprains are associated with neurological and mechanical disorders and affect somatosensory functions including proprioception [19]. In this study, the effect of these exercises on people with acute ankle sprain injury has been investigated, unlike previous studies that have been conducted on people with chronic ankle sprains or people with excessive foot pronation, or healthy people. Lee and Choi showed that intrinsic muscle exercises are effective in improving the dynamic balance of people with chronic ankle sprains who naturally have balance disorders [20]. Although the exercises performed for plantar muscles in the study of Lee and Choi were different from the selected exercise of this study. Lee et al. in a study on people with chronic ankle sprains, showed SFE to be more effective than proprioceptive exercises for dynamic balance [19]. When it comes to comparing the effectiveness, Veltrie compared the effect of intrinsic plantar muscle exercises with conventional exercises that focus on extrinsic muscles and showed that both groups of exercises were effective on dynamic balance, foot posture, and performance of hockey players [21]. Moon et al. investigated the immediate effect of SFE in patients with foot overpronation. The results of this study showed that performing only one session of this exercise in this group of patients is also useful and improves dynamic balance [18].

Despite the importance of proprioception and dynamic balance in preventing primary and secondary injuries [4], no study has been conducted to investigate the effect of intrinsic muscle exercises in patients with sub-acute ankle sprain. This study evaluates the effect of SFE on the dynamic balance of patients with primary sub-acute ankle sprain injury; therefore, this study finds out whether this type of exercise can be a more effective treatment for improving balance in people with primary subacute sprained ankle injuries.

Materials and Methods

Study participants

A total of 32 people with ankle sprains participated in this randomized clinical trial. This study was conducted from September 2022 to May 2023. The method for selecting the participants was the convenient sampling method, based on which samples were called from the people who were referred to three private clinics in Tehran City, Iran, and met the inclusion and exclusion criteria. People between the ages of 18 and 45 years [22] in 5 to 14 days post-injury [22, 23] of grade 1 and 2 lateral sprains according to the diagnosis done by an orthopedic specialist [24] were included in the study. If subjects had a fracture, needed a cast, or immobility after injury for more than 2 weeks [22], ankle syndesmosis injury, inability to bear full weight, history of injury to the target ankle in the last 12 months [25], a history of more than one-time ankle sprain injury [26] and diabetes, neurological, and systemic diseases were excluded from the study. Subjects (n=32) were randomly divided into two groups (SFE group [n=16] and control group [n=16]).

Table 1. Anthropometric characteristics of each group

Characteristics	Mean±SD/No.		P
	SFE	CG	
Age (y)	31.56±5.83	28.67±5.35	0.16
Height (cm)	167.81±5.09	170.19±6.77	0.27
BMI (kg/m²)	23.84±2.45	24.57±2.68	0.43
Gender (F/M)	6/10	4/12	0.7

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Notes: Independent t-test and chi-square test were used. There is no significant difference in anthropometric characteristics between groups.

Abbreviations: SFE: Short foot exercise; CG: Control group; BMI: Body mass index; F: Female; M: Male.

The anthropometric characteristics of each group are described in Table 1. There is no significant difference in the anthropometric characteristics between groups.

Study design

This study is a randomized controlled trial. Following the approval of this study by the Ethics Committee of Tehran University of Medical Sciences, the participants entered the study after signing the consent form and filling out the questionnaire. The sample size was calculated using G*Power software, version 3.1, a first type error of 0.05, power 80%, and based on previous studies [22, 27]. Allocation of patients to groups was done using papers with random numbers written on them. The primary outcome was dynamic balance and the secondary outcome was pain and ankle dorsiflexion range of motion. The outcome measures were evaluated before and after treatments.

Outcome measures

Dynamic balance

Dynamic balance was evaluated with the star excursion balance test (SEBT). This method is a reliable and valid test for predicting the risk of lower limb injuries and measuring dynamic balance [28]. Balance was evaluated in eight directions: Anterior, posterior, medial, lateral, anteromedial, anterolateral, posteromedial, and posterolateral. Before the start of the test, the participants were taught how to perform the test correctly. Each patient practiced four to six times in all eight directions, and after 5 min of rest, the main test began. The participants were asked to stand barefoot in the center of four crossing lines, with hands on the hips, and then, while putting weight on the injured leg, reach the farthest possible point in each direction with the other leg. This touch should be done very lightly with the big toe. The examiner marked the touched points. The test was repeated three times in each direction and the average distance in each direction was obtained. If the patient puts his foot down or moves the fixed leg to maintain balance, the test is not accepted and is repeated [28]. The obtained distances were standardized to the length of the lower limb as a percentage and were used for statistical analysis [28].

Pain

Pain intensity was evaluated by a numeric pain rating scale. It is a simple and common tool to measure pain in clinical studies and clinics [29]. The people participating in the study were asked to determine the maximum pain in the injured area during the past 24 h from zero, which indicates the least amount of pain, to ten, which indicates the maximum amount of pain [29].

Ankle dorsiflexion range of motion

In this study, ankle dorsiflexion range of motion was measured up to the threshold of pain onset. For the measurement, the participants were asked to sit on a chair so that their feet did not touch the floor. The center of the goniometer was set on the lateral malleolus and the stationary arm was aligned with the fibula, while the patient performed dorsiflexion from the neutral position, the moving arm moved parallel to the fifth metatarsal. The measurement was repeated three times and the average of three repetitions was used for statistical analysis [30].

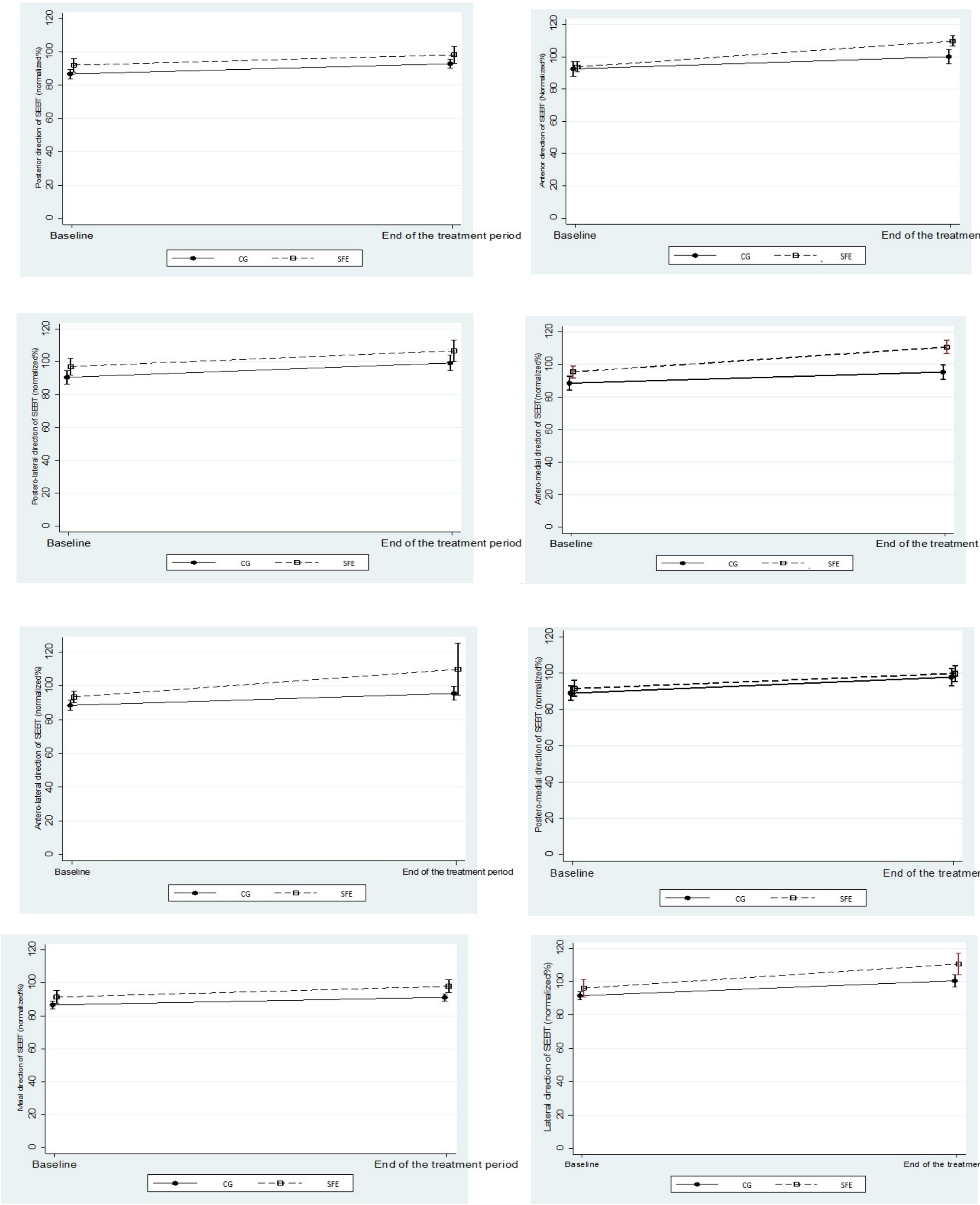

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Figure 1. Mean and 95% confidence interval of each direction of star excursion balance test before and after treatment protocols

Treatment protocols

Both groups received routine treatment protocol, including transcutaneous electrical nerve stimulation electrical stimulation (100 Hz frequency and 100 s µ diversion) to reduce pain, pulse ultrasound (1 MHz frequency and up to power 3 W/cm^2), and range of motion exercises in pain-free range for three times a week for 4 consecutive weeks and a total of 12 sessions. In addition to routine treatment, patients in the intervention group also received the SFE. To perform the SFE, the patients were asked to contract the intrinsic muscles isometrically and lift the arches of the foot, so that the metatarsal head is closer to the heel. At the same time, the toes should not go into flexion or extension. The contraction should be held for 5s [17]. The participants had

Table 2. Comparing the results of the star excursion balance test, pain, and dorsiflexion between two groups using one-way analysis of variance/covariance

Variants	F	P	95% CI	Cohen d	Partial η^2
SEBT-Ant	45.36	<0.001*	8.67 (6.04 to 11.30)	2.38 (1.46 to 3.29)	0.61
SEBT-Post	0.01	0.9	-0.07 (-2.67 to 2.52)	-0.02 (-0.71 to 0.67)	0.0001
SEBT-Med	6.90	0.014*	2.60 (0.56 to 4.62)	0.96 (0.22 to 1.69)	0.19
SEBT-Lat	11.55	0.002*	4.78 (1.90 to 7.66)	1.23 (0.46 to 1.98)	0.28
SEBT-AM	49.42	<0.0001*	8.52 (6.13 to 11.17)	2.61 (1.64 to 3.55)	0.63
SEBT-AL	1.08	0.31	8 (-7.71 to 23.70)	0.38 (-0.32 to 1.08)	0.04
SEBT-PM	0.16	0.69	-0.55 (-3.33 to 2.23)	0.14 (-0.83 to 0.55)	0.005
SEBT-PL	0.1	0.93	0.13 (-2.99 to 3.26)	0.03 (-0.66 to 0.72)	0.0003
Pain	19.58	0.0001*	-0.96 (-1.40 to -0.51)	-1.57 (-2.31 to -0.74)	0.4
DF Range	6.62	0.025*	2.55 (0.35 to 4.75)	0.84 (0.11 to 1.56)	0.16

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Abbreviations: SEBT: Star excursion balance test; Ant: Anterior; Post: Posterior; Med: Medial; Lat: Lateral; AM: Anteromedial; AL: Anterolateral; PM: Posteromedial; PL: Posterolateral; DF: Dorsiflexion.

Notes: * shows statistically significant associations at P≤0.05.

to perform this exercise for three sets of ten repetitions. Rest time between sets was 2 min [31]. According to the principle of progressive overload, the training intensity was divided into three levels. In the first week, the exercises were performed in a sitting position, and in weeks 2-3 were upgraded to a standing position on two legs, in the fourth week, were progressed to a standing position on one leg [32].

Data analysis

Statistical analysis was performed using the SPSS software, version 21. The Shapiro-Wilk test was used to evaluate the normality of data (P>0.05). Meanwhile, the independent t-test was used for intergroup comparison of quantitative demographic information (P>0.05). The result of the chi-square test also showed that there is no statistically significant difference between the two groups in terms of gender, and the two groups are similar in terms of male and female distribution (P>0.05). The one-way analysis of variance/analysis of covariance test with baseline adjustment was used for intergroup comparison. The paired t-test was used for intragroup comparison. Meanwhile, Cohen d effect size and partial η^2 were used to determine the effect size of the treatment. The interpretation areas for Cohen d are as follows [33]: Effect size <0.2 = ineffective area, 0.2 to 0.49 = low effectiveness area, 0.5 to 0.79 = moderate effectiveness zone, and higher than 0.8 = high effectiveness zone. The interpretation areas of partial η^2 are as follows [34]: Effect size between 0 and 0.021 = ineffective area, 0.022 to 0.059 = low effectiveness area, 0.06 to 0.10 = moderately effective area, and higher than 0.11 = area with large effect. The level of significance in the present study was considered 0.05. Intergroup analysis showed that both SFE and control groups experienced a significant increase in all components of dynamic balance and dorsiflexion range of motion compared to before the treatments (P<0.05). Furthermore, pain intensity decreased significantly in both groups. Figure 1 displays the mean values with a 95% confidence interval of each direction of SEBT before and after treatment protocols in both groups.

Results

The results of the one-way analysis of variance/ analysis of covariance with the control of baseline values showed that the distances reached in anterior, medial, lateral and anteromedial directions were more than the control group and this difference was statistically significant (P=0.001, P=0.002, P=0.014, P=0.0001). In addition, both Cohen d and Partial η2 effect sizes confirmed the high effectiveness of SFE compared to routine treatment alone on the dynamic balance of these directions of the SEBT (Table 2). The average pain intensity in the SFE group was significantly lower than the (P=0.0001). In addition, based on the effect size of Cohen d and Partial η2, adding SFE to routine treatment, compared, had a high effect on reducing the intensity of pain. Ankle dorsiflexion range of motion was also significantly bigger in the SFE group than in the control group (P=0.025)

Discussion

This clinical trial compared the effect of routine treatment alone with the combination of routine treatment and SFE on pain, ankle dorsiflexion range of motion, and dynamic balance outcomes.

The results of intragroup analysis showed the effectiveness of both protocols in improving all the outcome measures. Previous studies indicate that most sprains initially cause pain and swelling along with joint kinetic problems [19], the improvement achieved in these two groups can be under the indirect effect of the modalities used on pain or because of the natural and biological process of healing of the injured ankle. Furthermore, to complete the SEBT, subjects had to perform 24 movements with the injured ankle, which made this test time-consuming and tiring [35]. This could have more adverse effects on the initial assessments than the final assessments since the initial SEBT should have been performed only 5 to 14 days post-injury and subsequent immobilization. However, comparisons showed a significant improvement in dynamic balance in the SFE group compared to the CG.

SFE has been widely used to strengthen the intrinsic muscles of the foot [18]. These exercises are sensorimotor techniques to improve proprioception and postural stability [19]. Based on the study done by Rothermel et al. SFE improves neuromuscular activity [36]. McKeon et al. [32] and McKeon and Fourchet [37] introduced the term “foot core system”. They claimed the strength of the intrinsic foot muscles improves the overall stability of the lower limb. Lee et al. showed the superiority of SFE training on sensorimotor performance compared to a proprioceptive exercise. They demonstrated that 8 weeks of training could improve proprioception, and overall dynamic balance in patients with chronic ankle instability [19]. Also, in the study of Lee and Choi, intrinsic muscle exercises were reported to be effective for dynamic balance in patients with chronic ankle instability. After 6 weeks, these exercises significantly improved the dynamic balance of these patients in all three directions of the modified SEBT (Y balance test) [20]. In the present study, these exercises have been effective in improving dynamic balance in four directions, anterior, medial, lateral, and anteromedial, out of the eight directions of the SEBT. To explain this difference in the anterior and posterior directions, perhaps the difference between the SEBT and Y balance test can be considered. Fullam et al. pointed out that the distance reached in the anterior direction is less for the Y balance test compared to the SEBT, but there is no significant difference in the reached distance in the posteromedial and posterolateral directions [35]. By examining the kinematic movements of the hip, knee, and ankle joints in healthy people, they observed that for the anterior direction of the Y balance test, more flexion is needed in the hip joint [35]. In the SEBT, subjects apply only a slight downward pressure to reach the maximum distance. For this reason, to maintain balance at the end of the movement, they have to limit trunk and hip flexion [35]. In the lunge exercise, extension in the trunk causes a decrease in flexion in the hip joint [38]. In other words, the observed difference between the anterior and posterior directions in this study may be related to the hip joint. In the study of Gribble et al., it has been suggested that the angular displacement of the knee and hip joints in the sagittal plane affects the outcome of the SEBT [28]. In addition, recent studies have reported a strong correlation between anterior displacement and available ankle dorsiflexion range of motion [39]. Another difference that may have caused this discrepancy is the difference in target patients.

Part of the improvement in foot dorsiflexion range can be attributed to the improvement of pain. Pain acts as an inhibitor and limits the normal range of motion. This improvement in the range of motion in both treatment groups can be attributed to the relationship between pain and performance explained by the pain interference theory [40]. Accordingly, the ability of voluntary contraction decreases under the influence of Pain Sensation consequently the performance of muscles and finally the overall function of the body is affected [40]. In addition, the extrinsic muscles of the foot are the movers, while the intrinsic muscles are involved in the stability of the medial longitudinal arch and proprioception. SFE exercises focus on the activation and strengthening of the intrinsic muscles. Activation of intrinsic muscles and improvement of proprioceptive sensation caused by these exercises are effective on arthrokinematics movements and therefore these exercises can improve ankle range of motions including dorsiflexion.

In some studies, the relationship between functional disorders of the plantar fascia, hamstring shortening, and ankle joint movement limitation has been proposed [41, 42]. The plantar intrinsic muscles are part of the back-line superficial fascia, which includes the plantar fascia, Achilles tendon, Triceps Surae muscle, hamstrings, sacrotuberous ligament, and sacrolumbar fascia [43, 44]. In their study, Sulowska-Daszyk et al. concluded that intrinsic plantar muscle exercises can improve the flexibility of muscles in the more proximal parts of the body in myofascial chains and the quality of movement patterns [45]. Therefore, the results of the studies can be explained by the existence of a connection between the foot and the upper parts of the body in the fascia system.

Past studies often investigated the effectiveness of SFE on outcomes such as the strength of the intrinsic foot muscles, height of the medial longitudinal arch of the foot, and dropping of the navicular bone in foot injuries. However, less attention was paid to the effectiveness of these exercises in the improvement of pain sensation [27, 36, 46, 47]. Considering that pain is one of the most common complaints during activity and movements in the initial phases of ankle sprain, in this study the pain intensity was evaluated based on the NPRS. The comparison between the two groups showed that after the end of the treatment period, the average ankle pain in the SFE group was significantly lower than the CG. In addition to statistical significance, Cohen's d and Partial η^2 confirmed the high effectiveness of routine treatment plus SFE on pain reduction compared to routine treatment alone. It is reported in previous studies that proprioceptive exercises facilitate afferent messages and sensory feedback and improve sensorimotor performance [6]. Arguing that intrinsic plantar muscle exercises are effective on proprioception due to the location of these muscles and the sensory receptors within them [32], the reduction of pain in the SFE group was in line with previous studies. In a study, Lazarou et al. investigated the effect of two different proprioceptive and balance exercises on improving range of motion and pain in patients with ankle sprains and concluded that these exercises can be effective in improving range of motion and reducing pain [48]. However, due to limited studies on the effect of proprioceptive exercises on pain and range of motion in people with ankle sprains, this relationship cannot be confirmed with certainty.

Ankle sprains commonly result in a pronation position in the foot, which leads to navicular dropping. This condition is associated with the risk of entrapment of the Tibial nerve and decreased sensation in the medial ankle [49]. SFE can increase the navicular bone height by increasing the strength of the intrinsic foot muscles and increasing the medial longitudinal arch of the foot, which improves the sensory function of the ankle [50]. The sensory part of the Tibial nerve is specifically involved in the positional sense of the ankle joint, and the motor part of this nerve is involved in activating the posterior tibial muscles, flexor digitorum longus, and flexor hallucis longus [51].

To check whether the average difference in pain intensity between the two groups has reached the threshold of clinical significance, the minimum clinically important changes index was used. The minimum clinically important changes index shows the smallest changes that occur in an outcome following treatment, and that change is clinically important and significant [52]. Previous studies have expressed different thresholds for the clinically significant level of pain intensity in the chronic state ranging from 1.5 cm to 2.3cm on the visual analog scale, with an average of 2 cm and in the acute state between 1 cm and 1.3 cm. Namely in general between 12% to 20% pain reduction is considered as the clinically significant threshold [52, 53]. In the present study, the difference in average pain intensity between the groups without baseline adjustment was equal to 0.87 points, and considering baseline adjustment was equal to 0.96 points. These results show that despite the presence of statistical significance and high effect size in favor of the combination of SFE and routine treatment, the difference between the two groups was not clinically significant for the outcome of pain.

Conclusion

Adding SFE to the routine treatments can improve dynamic balance and ankle dorsiflexion range of motion more than routine treatments alone (transcutaneous electrical nerve stimulation, ultrasound, and range of motion exercises). However, the effect of SFE on pain intensity is not clinically significant. More studies along with follow-up can help to find definitive results about the impact and sustainability of SFE in people with primary ankle sprain.

Study limitations

This study faced some limitations. First was the referral of people with subacute sprains. They sometimes receive immobilization treatment at this stage, which limited the sample to those who could bear weight on the injured foot and undergo initial evaluations. Second, there was a time constraint for conducting the study and as a result the lack of follow-up for these patients. Third, only the clinical outcomes were used. The test laboratory was not used in this study. Because the purpose of SFE was specifically activating the intrinsic foot muscles, the use of laboratory tests such as electromyography or ultrasonography can offer a more precise perspective on the effectiveness of SFE and the level of activity of these muscles in people with ankle sprains.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Tehran University of Medical Sciences (Code: IR.TUMS.FNM.REC.1401.014), and the participants signed the consent form.

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Authors' contributions

Conceptualization, study design and final approval: All authors; Searching, screening, reviewing, and identifying the used assessment tools of the articles: Sepideh Sekkehchi, Siamak Bashardoust Tajali, Zinat Ashnagar; Data collection: Sepideh Sekkehchi and Fatemeh Majdi; Writing the manuscript and analyzing: Sepideh Sekkehchi.

Conflict of interest

The authors declared no conflict of interest.

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