Manual Therapy 23 (2016) 76–82

Contents lists available at ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math

Original article

Effect of stretching with and without muscle strengthening exercises for the foot and hip in patients with plantar fasciitis: A randomized controlled single-blind clinical trial☆

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ARTICLE INFO

Article history:
Received 31 December 2014
Received in revised form
12 October 2015
Accepted 19 October 2015

Keywords:
Plantar fasciitis
Muscle stretching exercises
Resistance training
Randomized controlled trial

ABSTRACT

Objective: To compare the effect of stretching with and without muscle strengthening of the foot alone or foot and hip on pain and function in patients with plantar fasciitis.
Design: Single blind randomized controlled trial.
Method: Eighty-three patients with plantar fasciitis were allocated to one of three treatment options for an eight-week period: Foot Exercise Group (FEG – extrinsic and intrinsic foot muscles), Foot and Hip Exercise Group (FHEG – abductor and lateral rotator muscles) and Stretching Alone Exercise Group (SAEG). Main measures: A visual analog scale for pain, the Foot and Ankle Outcome Score and the Star Excursion Balance Test. All evaluations were performed before treatment and after the last treatment session.
Results: Improvements were found in all groups regarding the visual analog scale, the pain, activities of daily living, sports and recreation, quality of life ($p < 0.001$) and other symptoms ($p < 0.01$) subscales of the Foot and Ankle Outcome Score as well as posterolateral movement, posteromedial movement and composite score ($p < 0.001$) on the Star Excursion Balance Test. No time-group interactions were found for any of the variables ($p > 0.05$).
Conclusions: All three exercise protocols analyzed led to improvements at eight-week follow-up in pain, function and dynamic lower limb stability in patients with plantar fasciitis.

1. Introduction

Plantar fasciitis (PF) is one of the most common conditions of the lower limbs. It is estimated that 10% of the population is affected at some time in life and two million Americans are treated for PF every year (McPoil et al., 2008). The multifactor etiology of this condition is not yet fully understood. Reduced strength of the plantar flexors, toe flexors and abductor hallucis muscles as well as a reduction in muscle volume in the forefoot are reported to contribute to PF (Kibler et al., 1991; Allen and Gross, 2003; Jung et al., 2011; Chang et al., 2012). Intrinsic and extrinsic muscles of the feet assist in supporting the medial longitudinal arch, absorption of impact during gait and lower limb function. However, studies on the effects of strengthening exercises for these muscles in patients with PF have reached inconclusive results (Soysa et al., 2012).

A low risk factor for PF is the reduction in strength of the abductor and lateral rotator muscles of the hips (McPoil et al., 2008; Martin et al., 2014). These muscles are important to the dynamic alignment of the lower limbs. A reduction in the strength of these muscles can lead to adduction and medial rotation of the hip and dynamic knee valgus, which is related to pronation of the foot (Khamis and Yizhar, 2007; Powers, 2010; Barton et al., 2012). Thus, strengthening the abductor and lateral rotator muscles of the hips may improve the dynamic alignment of the lower limbs and alleviate pain related to dynamic valgus (Snyder et al., 2009; Fukuda et al., 2010; Dolak et al., 2011). However, the effects of such exercises on PF are not yet understood.

☆ Clinical Trial Number: 05439012.0.0000.5505.

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http://dx.doi.org/10.1016/j.math.2015.10.006
1356-689X/

Stretching of the plantar fascia and triceps surae muscle is often employed in the conservative treatment of PF. Sweeting et al. (2011) performed a systematic review on the effects of stretching and concluded that this method can assist in reducing pain symptoms. However, there is no consensus on the ideal number of repetitions and frequency. Moreover, there is no evidence of the benefits of combining stretching and strengthening exercises.

The purpose of the present study was to compare the effect of stretching and strengthening of foot and hip with stretching alone on pain and function in patients with plantar fasciitis. We hypothesized that patients who received foot and hip strengthening would demonstrate greater improvements in pain and function than those who received just stretching.

2. Methods

2.1. Patients

Eighty-three male and female patients participated in a randomized controlled clinical trial and were allocated into one of the three treatment options for an eight-week period: Foot Exercise Group (FEG), Foot and Hip Exercise Group (FHEG) and Stretching Alone Exercise Group (SAEG). The participants were 20–60 years old, had a medical diagnosis of PF with symptoms for more than 30 days and were recruited through printed and digital media. The diagnosis was performed by physicians from Santa Casa de Santos.

Subjects were eligible to participate in the study if they had pain on the plantar face of the heel, or in the middle portion of the central band of plantar fascia with the following features: 1) pain upon palpation; or 2) insidious pain onset; 3) pain that was accentuated after long periods of upright activities or after rest, such as the first steps in the morning; and 4) a reduction in pain following light activities (McPoil et al., 2008; Renan-Ordine et al., 2011). The following were the exclusion criteria: history of lower limb surgery or trauma; a diagnosis of fibromyalgia, neurological disease, Achilles tendinopathy, metatarsalgia, acute ankle sprain, tarsal tunnel syndrome or heel pad syndrome; having undergone a strengthening or physiotherapy intervention for the lower limbs in the previous six months; body mass index (BMI) higher than 35 kg/m^2; or currently taking pain medication.

This study received approval from the Human Research Ethics Committee of the Universidade Federal de São Paulo (CAAE: 05439012.0.0000.5505) and is registered in Clinical Trials Registry. The patients received clarifications regarding the procedures and those who agreed to participate signed an informed consent statement. An examiner blinded to the allocation of the participants performed the evaluations before and after treatment. During the initial evaluation, general data were collected to determine similarities among the groups regarding age, height, BMI, weight-bearing range of motion of ankle dorsiflexion, duration of PF, level of physical activity, foot posture and lower limb dominance. Lower limb dominance was determined by asking the participant which leg he/she would use to kick a ball (Brown et al., 2014). Foot posture was evaluated using Foot Posture Index (FPI) (Redmond et al., 2008).

The level of physical activity was evaluated using the short version of the International Physical Activity Questionnaire (Matsudo et al., 2001). Randomization was performed by an independent researcher with the aid of the Excel™ program. Sealed, opaque envelopes were used for the allocation of the individuals to the different groups.

2.2. Interventions

The total intervention period was eight weeks. The volunteers in each group received information on PF and usual medical care, instructions, an explicative chart on the stretching exercises and a check list to record the frequency of daily stretching exercises. The volunteers in the FEG and FHEG also underwent two weekly sessions of strengthening exercises (total: 16 sessions) at a physical therapy clinic with the assistance of a physical therapist. If a patient missed an exercise strengthening session, he/she was expected to replace the lost session within the same week.

The volunteers in the SAEG were followed up weekly at the physical therapy clinic to monitor the frequency and manner by which the daily exercises were performed. Exercises with elastic resistance (Thera-band®) were adjusted weekly according to visual observation of the physical therapist along with verbal feedback from the subjects. They were asked to execute every exercise movement in a correct manner so that the last movement was close to their concentric failure.

2.2.1. Stretching Alone Exercise Group

The SAEG performed four daily stretching exercises (three 30-s sets).

Stretching of the hamstrings and ankle plantar flexors (straight leg raise in the supine position). Self-stretching of the calf muscles: The patient leaned forward in the standing position with the affected foot farther away from the wall, while keeping the heel on the floor; the soleus muscle was emphasized with the knee flexed and the gastrocnemius muscle with the knee extended. Self-stretching of the plantar fascia: in the sitting position, the patient crossed the affected foot over the contralateral thigh and performed passive extension of the metatarsophalangeal joints (Fig. 1).

In the first session, the volunteers were instructed on how to correctly perform the exercises. The frequency and manner by which the exercises were performed were monitored once a week.

2.2.2. Foot Exercise Group

The FEG performed the same stretching exercises as the SAEG as well as strengthening exercises for the intrinsic and extrinsic muscles of the foot (Fig. 2). Toe curl exercise (three sets of 15 repetitions): the volunteers pulled a towel along a smooth surface with the toes; gradual resistance was achieved with 1 and 2 Kg weights placed on the towel (Young et al., 2001). Short foot exercise: with one foot on the ground, the volunteer brought the heads of the metatarsals to the heel without removing the forefoot from the ground or flexing the toes, thereby shortening the foot in the anteroposterior direction and elevating the medial longitudinal arch; three 1-min sets were performed, alternating the feet (Jung et al., 2011; Mulligan and Cook, 2013). The invertors, evertors (in side-lying position) and dorsiflexors (in supine position) were strengthened using elastic resistance. For the plantar flexors, an inclined (25°) board was used, on which the volunteers remained standing and elevated their heels from the board (three sets of 10 repetitions).

2.2.3. Foot and Hip Exercise Group

The FHEG performed the same exercises as the SAEG and FEG as well as exercises for the abductor and lateral rotator muscles of the hip using elastic resistance (three sets of 10 repetitions). The exercise for the lateral rotators was performed with the volunteer seated on massage table adjusted to position the hip at 60°. The abductors were strengthened with three exercises: in the side-lying position with limb to be strengthened positioned on top; in the standing position; and side-stepping with elastic resistance in the distal region of the thigh (Fig. 3).

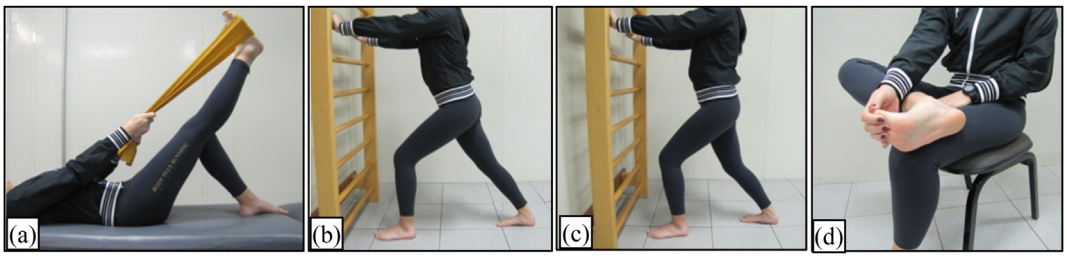

Fig. 1. Stretching Alone Exercise Group. (a) Straight leg raise in supine position. (b) Plantar flexors muscles stretch with knee extended. (c) Plantar flexors muscles stretch with knee flexed. (d) Plantar fascia stretch.

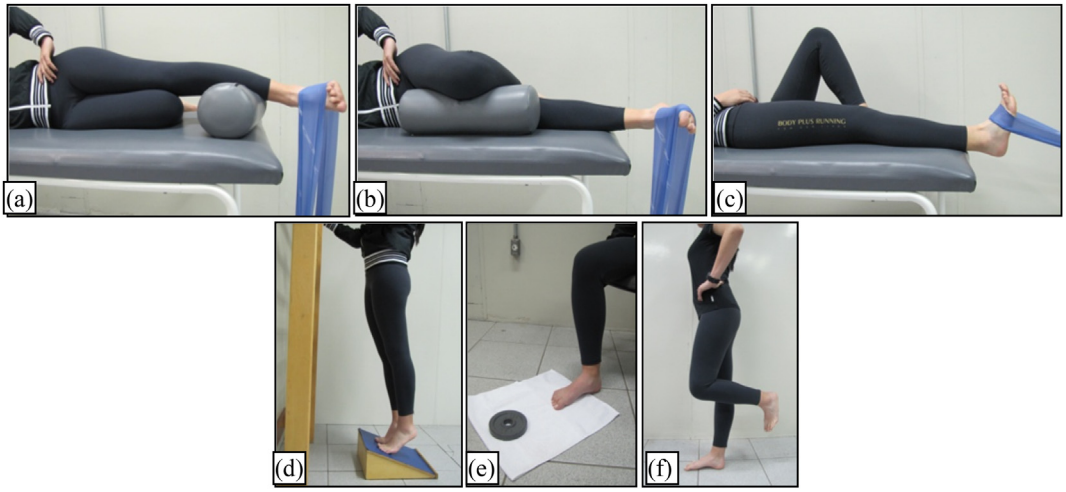

Fig. 2. Foot Exercise Group. (a) Evertors muscles strengthening. (b) Invertors muscles strengthening. (c) Dorsiflexors muscles strengthening. (d) Plantar flexors muscles strengthening. (e) Toe curl exercise. (f) Short foot exercise.

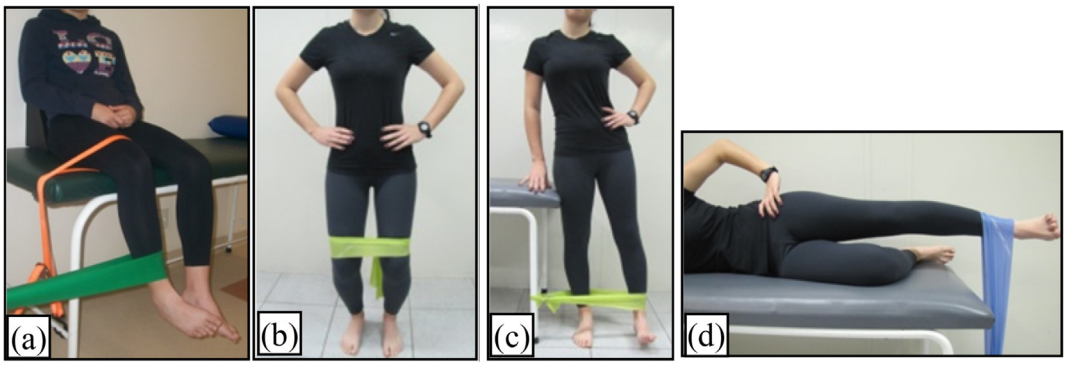

Fig. 3. Foot and Hip Exercise Group. (a) Hip external rotation. (b) Side-stepping. (c) Standing position. (d) Side-lying position.

2.3. Outcome measures

The visual analog scale (VAS) measuring 10 cm in length marked from 0 (absence of pain) to 10 (worst imaginable pain) was used to determine the degree of pain during the first steps of the day (VAS first) and at the end of the day (VAS end). The minimally clinical important difference (MCID) was 0.8 cm and 0.9 cm for average pain and 2 cm for pain on first step (Martin et al., 2014).

The Foot and Ankle Outcome Score (FAOS) was used to evaluate function related to foot and ankle problems. This measure contains five subscales: pain, other symptoms (stiffness, swelling, crepitus and limited range of motion), activities of daily living, sports & recreation and quality of life. Each subscale is scored from 0 to 100 points, with higher scores denoting better function. The volunteers were instructed to consider the week that preceded the evaluation. The Portuguese-language version has inter-rater and intra-rater intraclass correlation coefficients (ICC) of 0.9 and 1.0 (Imoto et al., 2009).

To evaluate lower limb stability and dynamic balance, we used the Star Excursion Balance Test (SEBT). After a visual demonstration and verbal instructions, the volunteers were positioned on one leg at the center of three lines (two posterior lines at a 90° angle and at 135° in relation to the anterior line) and they were asked to move the free limb seven times in each direction. Only the seventh attempted was measured. Composite score was calculated by dividing the sum of maximum anterior (A), posteromedial (PM) and

posterolateral (PL) movements by three times leg length (LL) and multiplied by 100 [(A + PM + PL/3 × LL) × 100]. Each movement was calculated by the distance reached divided by LL and multiplied by 100 (Filipa et al., 2010).

Intra-rater reliability of SEBT and FPI was assessed in a pilot study with 22 subjects using the $ICC_{3,1}$. Pilot testing of the SEBT produced an ICC of 0.92 for anterior reach, 0.94 for posterolateral reach and 0.93 for posteromedial reach. Intra-rater reliability of the FPI produced an ICC of 0.99.

2.4. Data analysis

The VAS for pain on first step was used to calculate the sample size, considering a MCID of 2 (Martin et al., 2014), a standard deviation of 2.1 and a 20% of dropout rate. For an 80% test power and 5% level of significance, the minimum size for each group was determined to be 25 volunteers. Patients that missed two consecutive exercise sessions or performed less than 70% of the daily stretching exercises were excluded from the revaluation. Analyses were performed in accordance to intention-to-treat (ITT) principle, which participants were analyzed according to their original treatment group assignment.

Continuous data were expressed as mean and standard deviation. Categorical data were expressed as frequency and percentage. Kolmogorov–Smirnov was used for testing data normality. Fixed-factor analysis of variance (ANOVA) was used to compare the initial continuous variables among groups, the chi-square test or Fisher's exact test was used for the categorical variables, and Kruskal–Wallis was used for variables not normally distributed. Repeated-measures ANOVA and the Bonferroni correction for multiple comparisons were used to analyze variables at different times and among groups, and non-normal distributed variable were analyzed with Friedman analysis of variance and Kruskal–Wallis ANOVA with multiple comparison of mean ranks for individual comparisons. The Statistica 12 program was used for the statistical analysis, with the level of significance set to $p < 0.05$.

3. Results

Among the 365 patients originally recruited, 282 were excluded based on the eligibility criteria: 171 were not within the stipulated age range; 17 had symptoms for less than 30 days; 20 refused to participate; six had a BMI higher than 35 kg/m^2; seven were taking pain medications; and 61 had an associated disease that could predispose the individual to heel pain, altered alignment, alter sensitivity or impair the healing process. Thus, 83 patients were randomly allocated to the groups. Four declined to participate before treatment and 54 (65%) were evaluated after the eight-week interventions. In the follow-up there was a loss of nine volunteers (34%) in the FEG, seven (25%) in the FHEG and nine (32%) in the SAEG (Fig. 4).

No significant differences among groups were found regarding the initial characteristics of the patients in the different groups or those who were either excluded or dropped out of the study ($p > 0.05$) (Table 1). The following were the characteristics of the excluded patients: mean height of 164 ± 9 cm, mean weight of 79 ± 13 Kg, mean BMI of 29 ± 4 kg/m^2, mean age of 43 ± 8.1 years, mean FPI of 2.44 ± 4.1 and mean symptoms duration of 12.3 ± 8.3 months. Eighteen volunteers were female, 11 were categorized as highly physically active and 14 had bilateral PF.

Improvements were found in all groups regarding VAS first, VAS end and the pain, activities of daily living, sports & recreation, quality of life ($p < 0.001$) and other symptoms ($p < 0.01$) subscales of the Foot and Ankle Outcome Score as well as PL movement, PM movement and composite score ($p < 0.001$) on the Star Excursion Balance Test. In contrast, no significant change was found in the A movement ($p = 0.17$). Moreover, no time-group interactions were found for any of the variables or difference between groups over time ($p > 0.05$) (Table 2).

4. Discussion

In the present study, the three different exercise protocols achieved similar improvements in pain, function and dynamic stability of the lower limbs in patients with PF. Thus, eight weeks of strengthening exercises of the intrinsic and extrinsic muscles of the feet and the abductors and lateral rotators of the hips combined with stretching exercises did not achieve better results in comparison to stretching alone.

Previous studies also reported the benefits of stretching in the PF treatment (DiGiovanni et al., 2003; Sharma and Loudon, 2010; Sweeting et al., 2011). However, the most appropriate frequency and duration of stretching exercises is still unknown (Sweeting et al., 2011). The stretching exercises protocols applied in the studies showing benefits from the treatment were diversified. DiGiovanni et al. (2003) submitted 101 patients to stretching of either the plantar fascia or triceps surae muscle with ten repetitions of 10 s three times daily. Radford et al. (2007) applied weight bearing stretching of triceps surae muscle 5 min daily and Hyland et al. (2006) and Sharma et al. (2011) used three repetitions of 30 s to stretch plantar fascia and triceps surae muscle, performed three times daily. The stretching exercises protocol used in the present study had significant improvement on pain and function, despite the difference from the previous studies. Further studies are needed to verify the most efficiency stretching exercise protocol for PF.

Due to the important role of the intrinsic and extrinsic muscles of the feet as well as the abductors and lateral rotators of the hips in the stabilization of the plantar arches and postural control of the lower limbs, the protocols that involved the strengthening of these muscles were expected to lead to greater improvements in pain and function in comparison to stretching alone (Snyder et al., 2009; Mulligan and Cook, 2013). However, the present findings suggest that the strengthening exercises had no additional effect on the outcomes. Similar improvement of the three treatment groups may occurred due to predominant benefits of stretching exercises on the first eight weeks of treatment. Nonetheless, the long-term effects and the influence of the strengthening on reducing relapses are not yet understood and merit further investigation.

No significant inter-group differences were found regarding the SEBT. The SEBT improvement on the three treatment groups may have occurred due to the increased ankle dorsiflexion range of motion, obtained through stretching exercises (Gribble et al., 2012). Further, the improvement may have occurred due to the reduction in pain (Menz et al., 2006). Pain on the sole of the foot, (Pradels et al., 2011) dorsum of the foot (Corbeil et al., 2004) and calf (Hirata et al., 2010) can influence the balance, posture and stability, through different physiological mechanisms, such as a change in the precision and velocity of the motor drive through the segmental reflex or an alteration in the excitability of motor nuclei and the motor cortex (Corbeil et al., 2004). It was expected that the patients that performed strengthening exercises would improve more than those who received only stretching, based on studies that have demonstrated the importance of the intrinsic and extrinsic muscles of the feet as well as the hip abductors and lateral rotators regarding the dynamic stability of the lower limbs (Powers, 2010; Kelly et al., 2012). However, the results suggest that the strengthening exercises had no effect on SEBT outcomes in patients with PF, which may have been obtained through pain reduction and increased range of motion.

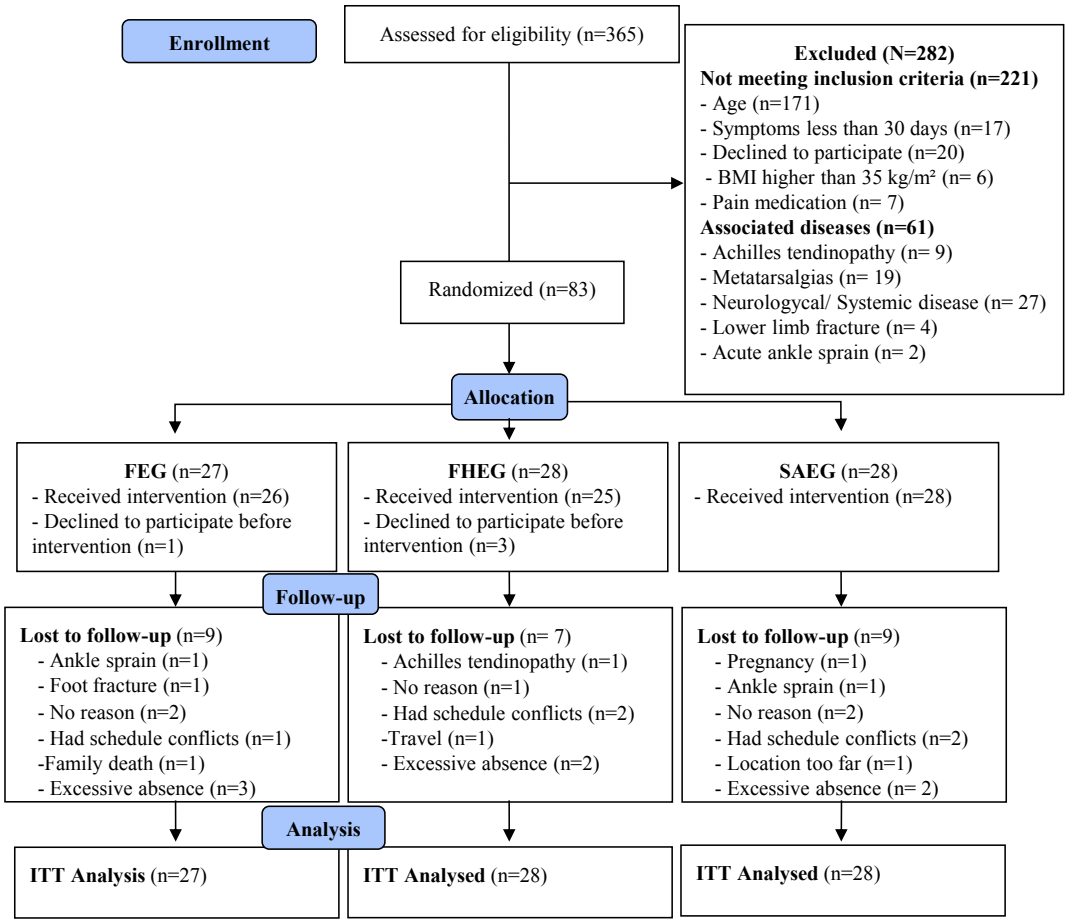

Fig. 4. Study flowchart.

Table 1
Baseline characteristics.

Variable	Groups			*p*
	FEG (n = 27)	FHEG (n = 28)	SAEG (n = 28)	
Height, cm[a]	167.2 ± 9.8	162.7 ± 10	165.6 ± 8.2	0.201
Body mass index, Kg/m²[a]	28.3 ± 4	29.2 ± 4.5	28.6 ± 4	0.721
Age, years[a]	47.7 ± 9.9	45.2 ± 12	44.5 ± 11.5	0.532
Sex, n woman (%)	21 (77)	23 (82.1)	22 (78.5)	0.912
Symptom duration, month[a]	19 ± 21.3	14 ± 13.6	21.8 ± 22.2	0.426
Ankle dorsiflexion, degree[a]	30.6 ± 6.8	31.2 ± 5.6	31.6 ± 6.1	0.854
Foot posture index[a]	2.2 ± 4.8	3.3 ± 4.5	3.1 ± 4.2	0.646
PF Bilateral, n (%)	13 (48)	15 (53)	12 (42)	0.724
Lower limb dominance				
Dominant, n (%)	14 (51)	13 (46)	18 (64)	0.388
Physical activity (IPAQ)				
High, n (%)	16 (59)	13 (46)	13 (46)	
Moderate, n (%)	6 (22)	11 (39)	13 (46)	0.365
Low, n (%)	5 (18)	4 (14)	2 (7)	

Abbreviations: PF, plantar fasciitis; SAEG, Stretching Alone Exercise Group; FEG, Foot Exercise Group; FHEG, Foot and Hip Exercise Group; IPAQ – International Physical Activity Questionnaire.
[a] Values are mean ± SD.

Some patients were excluded from the study due to injuries throughout the intervention. Two patients suffered ankle sprain, one suffered foot fracture and one had Achilles tendinopathy. The exercises did not have a direct relationship with ankle sprain or foot fracture, since the protocols offered no risks of such injuries. Radford et al. (2007) studied ten patients (22%) who performed stretching of the triceps surae and had adverse events, such as increased heel pain as well as pain in different regions of the leg, but the symptoms disappeared at the end of the treatment.

The sample of the present study had chronic PF, which may be a negative predictor for this disorder treatment (McClinton et al., 2015). However, the pain improvement in chronic patients was also reported by other studies using stretching exercises (Porter et al., 2002; DiGiovanni et al., 2003; Radford et al., 2007; Drake

Table 2
Outcome measures at baseline and after eight weeks of intervention.

Measure	Groups					
	FEG		FHEG		SAEG	
	Pre	Post	Pre	Post	Pre	Post
VAS first	6.5 ± 2.7	3.3 ± 2.8*	6.7 ± 3.3	4.1 ± 3.6*	6.5 ± 2.4	3.6 ± 3.3*
VAS end	6.5 ± 2.7	3.5 ± 3*	6.7 ± 2.8	4.1 ± 3.8*	6.4 ± 2.7	3.5 ± 3.4*
FAOS						
Pain	56.3 ± 17	72.9 ± 16*	46 ± 15	66.1 ± 20*	56.9 ± 17	71.2 ± 22*
Other symptoms	84.8 ± 14	87.8 ± 15**	84.5 ± 16	88.7 ± 10**	86 ± 13	90.7 ± 11**
ADL	68.7 ± 21	85.6 ± 13*	58.4 ± 19	75.2 ± 21*	68.8 ± 19	80.5 ± 19*
Sport and Recreation	48.7 ± 29	71.5 ± 26*	41.9 ± 25	65.7 ± 28*	50 ± 28	71 ± 29*
Quality of Life	34.2 ± 22	50.9 ± 25*	21.6 ± 17	40.8 ± 26*	29.2 ± 21	52.2 ± 23*
SEBT						
Anterior	56.3 ± 8	58.4 ± 10	59.2 ± 9	58.8 ± 6	56.2 ± 6	58.2 ± 7*
Posteromedial	81.1 ± 12	85.9 ± 10*	81.9 ± 6	85.7 ± 6*	81.4 ± 8	87.4 ± 9*
Posterolateral	63.5 ± 15	69.7 ± 15*	63.6 ± 14	71.2 ± 13*	64.2 ± 12	71.4 ± 11*
Composite	73.7 ± 19	77.7 ± 18*	75.7 ± 23	79.4 ± 22*	76.5 ± 24	82.7 ± 24*

Abbreviations: VAS first, Visual Analogue Scale during the first steps of the day; VAS end, Visual Analogue Scale at the end of the day; FAOS, Foot and ankle outcome score; ADL, Activities of Daily Living; SEBT, Star Excursion Balance Test; FEG, Foot Exercise Group; FHEG, Foot and Hip Exercise Group; SAEG, Stretching Alone Exercise Group.
Values are mean ± SD.
*$p < 0.001$ within group.
**$p < 0.01$ within group.

et al., 2011). Martin et al. (2014) noted that PF occurs generally in a chronic manner, in which symptoms duration is greater than one year prior to treatment. Then, when they undergo the treatment, they might experience some improvement in a short term. Elevated BMI is another negative predictor for the treatment and predisposes the injury to turn into chronic PF (McClinton et al., 2015). The present study considered BMI higher than 35 kg/m^2 as an exclusion criteria to maintain homogeneity between the groups. However, further studies are necessary to verify the effects of stretching and/or strengthening in patients with elevated BMI.

The main limitation of the present study was the lack of a non-treatment group. The non-treatment group is important to follow the natural progression of PF, however similar improvements of the groups might have not been influenced by the natural progression of PF based on patients' reports. Most of the patients reported plantar chronic pain, which difficult the spontaneous improvement on pain during the treatment time (McClinton et al., 2015).

Another limitation was the dropout rate, which was similar or higher than reported by previous studies involving stretching exercises (Porter et al., 2002; DiGiovanni et al., 2003; Sharma and Loudon, 2010). The dropout rate might have been influenced by non-observed improvement in pain in the early stage of the treatment (Sweeting et al., 2011), and may have been higher than that reported in previous studies due to the socio-cultural characteristics. These characteristics include change of treatment and evaluation place that occurred during the study and difficulty to access the treatment location. Also, we included in the dropout rate the volunteers that missed two consecutive exercise sessions which increases this rate in 8.5%. Due to the dropout rate, the number of patients reevaluated was smaller than that stipulated during the sample size calculation, which may have diminished the power of the study.

Moreover, no evaluation of muscle strength was performed due to the lack of adequate equipment, that could be used to compare initial muscular strength and verify homogeneity among the groups, and perform an additional statistical analysis by correlating the gaining of muscular strength with SEBT and reduction on pain values. Further studies are needed with a more numerous sample size, containing a non-treatment group to ensure that improvement is not a natural progression of PF, and evaluating muscle strength to compare the short-term and long-term effects of these exercise protocols on pain, function and the occurrence of relapse.

5. Conclusion

All three exercise protocols analyzed led to improvements at the eighth-week follow-up in pain, function and dynamic lower limb stability in patients with plantar fasciitis. The non-significant differences among the groups suggest that daily stretching is effective and protocols that combine stretching with strengthening do not achieve better results than stretching alone expressed by the outcomes analyzed in this population.

Acknowledgments

We gratefully acknowledge the financial support from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and Felipe Granado de Souza for statistical support.

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