

REVIEW

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A systematic review of the effects of strength training in patients with fibromyalgia: clinical outcomes and design considerations

Alexandro Andrade^{1,2*} , Ricardo de Azevedo Klumb Steffens^{1,2,3} , Sofia Mendes Sieczkowska^{1,2} ,
Leonardo Alexandre Peyré Tartaruga^{4,5}  and Guilherme Torres Vilarino^{1,2} 

Abstract

Background: Fibromyalgia (FM) is characterized by chronic and generalized musculoskeletal pain. There is currently no cure for FM, but palliative treatments are available. One type of treatment is strength training (ST). However, there is a need for more information on optimal training protocols, intensity, and volume needed to improve symptoms. The aim of this study was to analyze the effects of ST in the treatment of FM through a systematic review of experimental research.

Methods: Medical Subject Headings search terms and electronic databases including Scientific Electronic Library Online, PubMed, Science Direct, Web of Science, and Physiotherapy Evidence Database were used to identify studies.

Results: The inclusion criteria were met by 22 eligible studies. Most of the studies were conducted in the United States (36%), Finland (23%), Brazil (18%), and Sweden (18%). The studies showed that ST reduces the number of tender points, fatigue, depression, and anxiety, and improves sleep quality and quality of life in patients with FM. The intervention period ranged from 3 to 21 weeks, with sessions performed 2 times a week in 81.81% of the studies, at initial intensities of 40% of 1-repetition maximum. The repetitions ranged from 4 to 20, with no specific protocol defined for ST in FM.

Conclusion: The main results included reduction in pain, fatigue, number of tender points, depression, and anxiety, with increased functional capacity and quality of life. Current evidence demonstrates that ST is beneficial and can be used to treat FM.

Trial registration: CRD42016048480.

Keywords: Fibromyalgia, Resistance training, Health, Exercises, Therapy, Rehabilitation

Background

Fibromyalgia (FM) is a chronic disease characterized by generalized skeletal muscle pain [1, 2], and other common symptoms include fatigue, sleep disorders, depression, and excessive anxiety [3–6]. The pathogenesis of FM is still not well understood [7], and FM is

considered by some researchers to be a neurobiological disease caused by abnormal processing of pain [8]. Owing to the lack of markers that can identify the disease, the diagnosis is made through clinical examination, according to the guidelines of the American College of Rheumatology [1, 3].

As FM has no cure, treatments are palliative, and multidisciplinary approaches involving the use of medications, physical exercise (PE), and psychological treatments are recommended [4, 9–12]. PE has been advised in several studies and guidelines for the treatment of FM

* Correspondence: alexandro.andrade.phd@gmail.com

¹Health and Sports Science Center, CEFID / Santa Catarina State University – UDESC, Florianópolis, SC, Brazil

²Laboratory of Sports and Exercise Psychology - LAPE, Florianópolis, SC, Brazil
Full list of author information is available at the end of the article



[13–16], and the inclusion of aerobic, resistance, and water exercises has been strongly recommended [5, 15–17]. The severity of FM symptoms can affect the level of physical fitness, and patients commonly perform little physical activity because of pain [18–20].

The relationship between PE and FM has been investigated, and strength training (ST) has been compared with other PE modalities. Studies have shown that ST has favorable results on pain, sleep, depression, and the number of tender points [17, 21]. However, studies on the effect of PE present poor quality evidence owing to small sample sizes and methodological problems [22, 23]. Recent studies have attempted to better understand the effects of ST in patients with FM [21, 24–26]. However, research has emphasized physical aspects with conflicting results [27, 28]. Despite recent research on the effects of ST in patients with FM, the duration, frequency, and intensity required to improve the symptoms remain unknown because the protocols differ among studies [29–31]. Thus, there is no consensus on the use of ST in clinical practice. The aim of this study was to analyze the effects of ST in the treatment of FM through a systematic review of experimental research.

Methods

The present study followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [32]. The PRISMA Statement is a protocol that guides the construction of systematic reviews in a transparent and consistent manner using a checklist of 27 items and a 4-phase flow diagram [33]. This systematic review was registered as CRD42016048480 in the International Prospective Register of Systematic Reviews (PROSPERO) [34]. A primary goal of PROSPERO is to make known the intention to conduct a systematic review, in order to reduce duplication and to facilitate transparency in the review process [35].

Eligibility criteria

In order to include the entire publication period, no time limit was set. The eligibility criteria were determined according to the PICOS (Population, Intervention, Comparison, Outcomes, Setting) strategy.

Population

Adults 18 years and older with a diagnosis of FM according to the 1990 criteria of the American College of Rheumatology (1).

Intervention

Any intervention with ST or resistance training for patients with FM was included. We excluded studies with combined interventions, such as those with ST combined with aerobic training.

Comparison

With any other type of group (such as sedentary controls and healthy controls) and with other types of intervention (such as aerobic exercise and flexibility exercise).

Outcomes

All possible effects of ST and the intervention protocols used in the studies in patients with FM.

Type of study

Randomized or non-randomized trials reporting clinical outcomes demonstrating the effects of ST. The frequency of ST and the extent to which ST was provided were the minimum necessary data for a research to be defined as an intervention study. Revised articles, dissertations, theses, and congress abstracts were excluded.

Information sources

The studies were identified through electronic databases, including PubMed, Science Direct, Web of Science, Physiotherapy Evidence Database, and Scientific Electronic Library Online. The last survey was conducted in December 2017.

Search strategy

The search terms were defined by the researchers using the Medical Subject Headings (Table 1), and the search strategy in the PubMed database is shown in Additional file 1.

Study identification

The searches and selection of articles were independently performed by 2 researchers; in case of disagreement, a third party was asked to make the final decision. An initial analysis was performed based on reading the title. From these selected articles, the abstracts were read and the articles included in the review were read in their entirety. A review of the references and citations of these articles was also carried out in order to identify other potentially relevant studies. From the selected studies, an analysis of the use of ST for the treatment of patients with FM was performed.

Data extraction

For the analysis and discussion of the results, the following data were extracted: author and study design; study participant number, age, sex, and treatment group; type of exercise, time of intervention, intensity, and adherence (based on either the number of attending patients at the beginning and end of the study or from data provided by the authors); and conclusions of the study.

Quality of study and risk of Bias

This systematic review evaluated the quality of the included studies and the risk of bias using the Cochrane

Table 1 Search terms used in databases

Terms	Descriptors
1. Disease	"Fibromyalgia"
2. Exercise	"Resistance Training" OR "Strength Training" OR "Strength Training Program*" OR "Training Resistance" OR "Strengthening Program"
Combination	#1 AND #2

Collaboration Risk of Bias tool [36], which includes criteria to identify bias in the selected studies that can interfere with the interpretation and conclusion. Bias risk assessment was performed by 2 researchers. The kappa concordance index [37] between the reviewers for each of the criteria was determined, and differences were resolved by consulting a third reviewer for a final opinion.

Results

Identification and selection of studies

The first stage of selection using the databases identified 211 studies, with 1 additional study manually inserted. Sixty-two duplicate studies were excluded and 48 abstracts were selected after reading the titles. At the abstract review stage, 17 studies were excluded, of which 9 used combined exercise, 7 were congress abstracts, and 1 did not evaluate patients with FM. In the fourth stage, the complete texts of 31 studies were read; 5 were excluded because of the intervention protocol, 1 was a short communication, and 1 was a congress article. Thus, 22 studies were selected for the analysis, as shown in Fig. 1.

Characteristics of included studies

Of the 22 studies included in the review, the oldest was published in 2001 [38] and the most recent was published in 2017 [24, 39, 40] (Table 2). Most of the studies were conducted in the United States (36%, $n = 8$), followed by Finland (23%, $n = 5$), Brazil (18%, $n = 4$), Sweden (18%, $n = 4$), and Turkey (5%, $n = 1$). Women aged 18–65 years comprised the total sample, and the main variables analyzed were pain, strength, muscular activity, functional capacity, fatigue, quality of life, and sleep [24, 25, 27, 29, 38, 39, 41–44]. Among the tests used in the evaluations, the Fibromyalgia Impact Questionnaire, which evaluates the impact of FM on quality of life, was used in most of the studies [25, 27–29, 31, 45–48]. To measure strength, the 1-repetition maximum (1RM) was the most used test [27–29, 31, 38, 49, 50] and studies that verified muscle activity used electromyography [38, 41, 51–53]. The visual analogue scale was used to evaluate pain in most of the studies [29, 41, 42, 45, 48, 53]. Concerning adherence, most of the studies did not provide this information. Therefore, adherence was calculated based on the patients' attendance,

and an average adherence percentage of 84% (range, 54–100%) was obtained. Five studies provided the average attendance rate, ranging from 71 to 100%.

Summary of evidence and practical implications

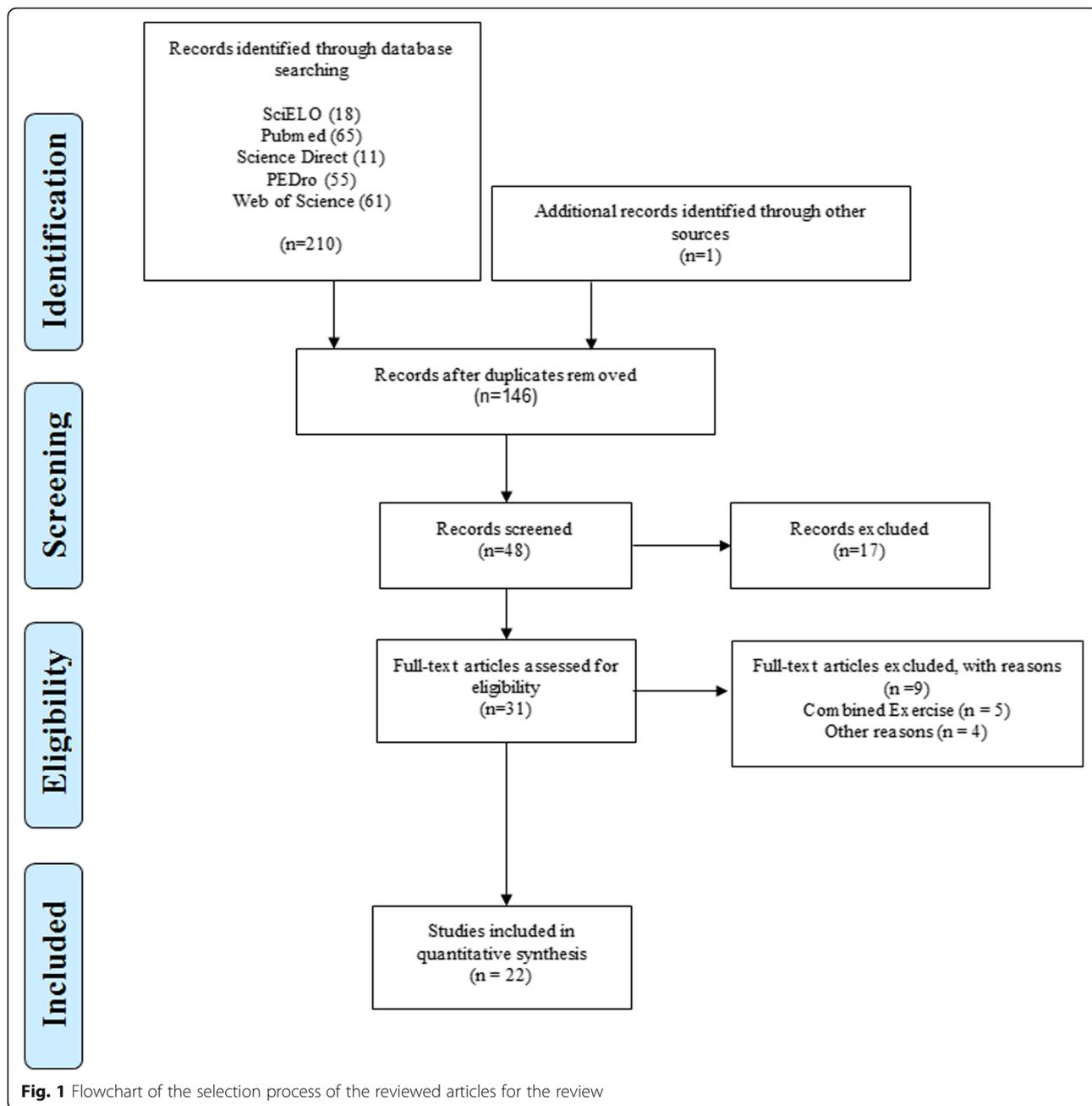
The analysis of the results revealed that ST reduced the symptoms of patients with FM, such as pain, fatigue, number of tender points, depression, and anxiety, with improved functional capacity and quality of life [24, 25, 27, 29, 38, 39, 41, 42] (Table 2), despite the different training protocols used.

When analyzing the training protocol, 81.81% of the studies submitted the patients to interventions twice a week, whereas only 13% (3 studies) submitted the patients to 3 sessions per week and 1 study verified the effect of a single session. Concerning the intervention time, the shorter studies lasted for 3 weeks whereas the longer studies lasted for 21 weeks. Most of the studies had an intervention time of 21 (22.72%), 12 (22.72%), 16 (18.18%), and 15 (18.18%) weeks. The studies used similar training protocols, starting with 40% of 1RM and progressing to 85%. During the training, exercises using machines and free weights worked the large and small muscle groups.

Pain was the most studied variable, showing a reduction after ST [27, 29, 30, 45, 53–55]. No study reported increased pain after or during the intervention period. Kayo et al. [48] found at the end of 16 weeks of intervention that only 41.4% of patients in the ST group were using pain medication, whereas in 80% of the patients in the control group regularly used pain medication. Other well-analyzed variables were strength, quality of life, heart rate variability (HRV), and depression. With regard to muscle strength, increases between 33 and 63% were observed after 21 and 16 weeks [41, 49]. In terms of the variability of heart rate, the effects of ST on patients with FM presented controversial results; however, the evidence shows little effect on this variable [49]. Studies analyzing quality of life and functionality showed that ST is effective in improving these variables [28, 29, 31, 41, 42, 45].

The most investigated psychological variable was depression. The studies of Jones et al. [45], Gavi et al. [29], and Assumpção et al. [40] showed that ST reduces depressive symptoms; however, the study of Ericsson et al. [25] did not find a significant difference after 15 weeks of intervention.

We also analyzed the results related to sleep quality. Andrade et al. [24] found that sleep disorders were reduced after ST and that sleep correlated with pain. The results of Ericsson et al. [25] also disclosed that ST yielded better results than relaxation sessions in improving sleep quality. In addition, another important result is that patients with FM presented similar responses to



those of healthy persons; thus, they recommended ST to assist in the treatment of patients.

The intervention protocols, results, and conclusions of each study are presented in Table 2.

Quality of studies and risk of Bias

The kappa concordance index between the two reviewers was 87.1% for all criteria. Of the 22 studies, 13 had low risk of adequate sequence generation bias; four were unclear regarding the risk of adequate sequence generation bias and six were not randomized. Only four studies had low risk of allocation concealment bias. Ten

studies had a high risk of blinded participant bias; only four had a low risk and eight were unclear. Twenty-one studies presented low risk of incomplete data bias. Similar findings were noted for selective results bias; only two studies were unclear. The descriptions of interventions (characteristics of exercises) were another source of bias, with only two studies having a high risk (Fig. 2).

Discussion

This systematic review aimed to analyze the efficacy of ST in the treatment of FM by examining the existing experimental research. The studies showed that the intervention

Table 2 Characteristics and results of experimental studies with strength training for patients with fibromyalgia syndrome

Study and Design	Sample	Intervention	Results	Conclusion
Hakkinen et al., (2001); RCT	21 women with FM (ST and CG) e 12 HC Age TF: 39 ± 6 years CG: 37 ± 5 years GS: 37 ± 6 years	Duration: 21 weeks; Weekly frequency: 2; Repetitions: Initially 15–20, from the 15th week; 5–10 Exercises: Supine, squats, extension and flexion of knees and trunk Adherence to ST: 100%	FM subjects increased their maximal and explosive strength and EMG activity to the same extent as the HC group. Moreover, the progressive strength training showed immediate benefits on subjectively perceived fatigue, depression, and neck pain of training patients with FM.	A similar maneuverability of the neuromuscular system occurs in women with FM and healthy women. ST is safe and can be used to decrease the impact of FM in the neuromuscular system
Hakkinen et al., (2002); RCT	21 women com FM, (ST and CG) and 12 HC Age TF: 39 ± 6 years CG: 37 ± 5 years GS: 37 ± 6 years	Duration: 21 weeks; Weekly frequency: 2; Series: 3–5 series per exercise; Intensity: 40–80% of 1RM; Repetitions: Initially 10–20, from the 14th week; 5–8. Exercises: leg press, extension and flexion of the knee, elbow and trunk, pulled high, adduction and abduction of the legs Adherence to ST: 100%	Maximal force increased by 18 ± 10% in the FM group, and by 22 ± 12% in the HC, while in the CG it remained unchanged. Maximum integrated EMG of the agonists (VL + VM/2) increased in HC by 22% and in the FM by 19%. Significant increases in the CSA of the QF were observed at 5 to 12/15 femur in FM and at 3 to 12/15 femur in HC, while in FM the CSA remained unchanged. A significant acute increase took place in the mean concentration of GH at pre-training in HC and in the FM, while at post-training the elevations after the loading remained elevated up to 15 min in HC and up to 30 min post-loading in the FM.	The time of neuromuscular and ST adaptations and the basal levels of anabolic hormones in women with FM are similar to healthy women
Jones et al., (2002); RCT	68 women (ST and FLEX); Age TF: 49.2 ± 6.36 years CG: 46.4 ± 8.56 years	Duration: 12 weeks; Weekly frequency: 2 Initially 1 series of 4–5, and progressively up to 12. Exercises: The main muscle groups were worked, but exercises were not specified. Adherence to ST: 85%	No statistically significant differences between groups were found on independent t tests. Paired t tests revealed twice the number of significant improvements in the strengthening group compared to the stretching group. Effect size scores indicated that the magnitude of change was generally greater in the strengthening group than the stretching group.	The ST group decreased the total pain score, the number of tender points, increased leg strength, shoulder strength, improved quality of life and reduced depression. ST showed better results than FLEX.
Valkeinen et al., (2004); RCT	36 women (26 FM and 10 HC) Age ST: 60.2 ± 2.5 years CG: 59.1 ± 3.5 years HC: 64.2 ± 2.7 years	Duration: 21 weeks; Weekly frequency: 2; Initially 3 series of 15–20 progressively up to 4 series of 8–12 and up to 5 series of 5–10 . Exercises: The main muscle groups were worked, but exercises were not specified. Adherence to ST: 100%	The mean increases in maximal extension force during the training period in groups FM and in HC were 32 ± 33% and 24 ± 12% respectively and those of flexion were 13 ± 20% and 24 ± 17%. Explosive force of the extensors increased in both FM and in HC. The integrated EMGs of the vastus lateralis and medialis muscles increased in both FM and HC. Muscle forces and EMGs in group CG remained at the basal level. Walking speed, stair-climbing time and the HAQ index improved in group FM. The changes in the number of tender points and in perceived symptoms were in favors of the training group FM.	It improved the functional capacity and the strength in the extensor and flexor muscles of the knee in both groups submitted to the TF (FM and healthy). Patients with FM respond similarly to TF that healthy people of the same age.
Valkeinen et al., (2005); RCT	26 women (ST and CG); Age ST: 60 ± 2 years CG: 59 ± 4 years	Duration: 21 weeks; Weekly frequency: 2; Initially 3 series of 15–20; weeks 15 to 21 went to 5–10. Intensity: progressive increase of 40% to 80% of 1 RM Exercises: 6 to 7 for the main muscle groups Adherence to ST: not reported the	All patients were able to complete the training. In FM strength training led to increases of 36% and 33% in maximal isometric and concentric forces, respectively. The CSA increased by 5% and the EMG activity in isometric action by 47%	The ST increases strength, cross-sectional area and voluntary muscular activation in elderly women with FM. Patients with FM can be submitted to higher intensities without increasing symptoms

Table 2 Characteristics and results of experimental studies with strength training for patients with fibromyalgia syndrome (Continued)

Study and Design	Sample	Intervention	Results	Conclusion
		number of dropouts	and in concentric action by 57%. Basal serum hormone concentrations remained unaltered during strength training. The subjective perceived symptoms showed a minor decreasing tendency (ns). No statistically significant changes occurred in any of these parameters in CG.	
Kingsley et al., (2005); RCT	29 women (ST and CG); Age ST: 45 ± 9 years GC: 47 ± 4 years	Duration: 12 weeks; Weekly frequency: 2; 1 serie of 8–12 Intensity: 60 to 80% of 1RM Exercises: Supine, extension and flexion of knee and elbow, low row, shoulder and lumbar development Adherence to ST: 54%	The strength group significantly improved upper and lower body strength. And upper-body functionality measured by the Continuous-Scale Physical Functional Performance test improved significantly after training. Tender point sensitivity and fibromyalgia impact did not change.	At the end of study was a significant increase in muscle strength and improvement in functional capacity components in the ST group.
Valkeinen et al., (2006); Non RCT	23 women (13 ST and 10 CG) Age ST: 60 ± 2 years CG: 54 ± 3 years	Duration: 21 weeks; Weekly frequency: 2 Intensity: Started with 50% of 1RM and progressively up to 80%; Exercises: two Exercises for knee extensors and 4–5 Exercises for the rest of the body Adherence to ST: 100%	The ST led to large increases in maximal force and EMG activity of the muscles and contributed to the improvement in loading performance (average load/set) at week 21. The fatiguing loading sessions typically applied in strength training before and after the experimental period caused remarkable and comparable acute decreases in maximal force and increases in blood lactate concentration in both groups. Acute exercise-induced muscle pain increased similarly in both groups, and the pain level in women with FM was lowered after the 21-week training period.	An increase in maximal strength, blood lactate concentration and decrease in pain of the ST group was observed.
Bircan et al. (2008); RCT	26 women (ST and AE) Age ST: 46 ± 8,5 years AE: 48.3 ± 5.3 years	Duration: 8 weeks Weekly frequency: 3 Initially 1 serie of 4 repetitions and progressively up to 12 repetitions; Exercises were not specified, however, free weights were used and the patient's body weight Adherence to ST: 100%	There were significant improvements in both groups regarding pain, sleep, fatigue, tender point count, and fitness after treatment. HAD-depression scores improved significantly in both groups while no significant change occurred in HAD-anxiety scores. Bodily pain subscale of SF-36 and physical component summary improved significantly in the AE group, whereas seven subscales of SF-36, physical component summary, and mental component summary improved significantly in the ST group.	Aerobic exercise and strengthening exercise were similarly effective at improving symptoms, tender point count, fitness, psychological status, and quality of life in fibromyalgia patients.
Figueroa et al. (2008); RCT	19 women (10 FM and 9 HC) Age ST: 50 ± 10 years HC: 49 ± 8 years	Duration: 16 weeks Weekly frequency: 2 1 serie of 8–12 repetitions; Intensity: Initially 50% 1RM and progressively up to 80%; Exercises: Supine, knee extension and flexion, Leg press, low row, shoulder development (performed on machine) Adherence to ST: 67%	RR interval, total power, log transformed (Ln) squared root of the standard deviation of RR interval (RMSSD), low-frequency power and BRS were lower, and HR and pulse pressure were higher in women with FM than in healthy controls. After ST, mean (SEM) total power increased, RMSSD increased and Ln of high-frequency power increased in women with FM. Upper and lower body muscle strength increased by 63% and 49%, and pain perception decreased by 39% in women with FM. There were no changes in BRS, HR and BP after ST.	The ST improves heart rate variability, parasympathetic activity, pain and the strength of women with FM with autonomic dysfunction.
Kingsley	18 women	Duration: acute effect	Variables were similar in both groups	The results showed lower muscle

Table 2 Characteristics and results of experimental studies with strength training for patients with fibromyalgia syndrome (*Continued*)

Study and Design	Sample	Intervention	Results	Conclusion
et al. (2009); Non RCT	(FM and HC) Age 48,0 years (21–59 years)	One session 30 min of ST, 1 serie of 12; Exercises: 10 exercises, were not specified. Adherence to ST: 100%	at rest. HFnu decreased in controls and increased in women with FM post. LFnu increased in controls and decreased in women with FM. The LFnu/HFnu ratio increased in controls with no change in women with FM, and BRS decreased in controls but not in women with FM.	strength in the FM group and after acute ST, women with FM responded differently from controls, demonstrated by lower sympathetic and higher vagal modulation without altering baroreceptor reflex sensitivity.
Panton et al. (2009); RCT	21 women (ST e ST-C); Age ST: 50 ± 7 years ST-C: 47 ± 12 years	Duration: 16 weeks; Weekly frequency: 2; 1 serie of 8–12 repetitions; Exercises: Supine, knee extension and flexion, Leg press, low row, shoulder development (performed on machine). Adherence: 82.8%	Both groups increased upper and lower body strength. There were similar improvements in FM impact in both groups. There were no group interactions for the functionality measures. Both groups improved in the strength domains; however, only ST-C significantly improved in the pre- to postfunctional domains of flexibility, balance and coordination, and endurance.	The ST improved FM impact on quality of life and strength. The practice of chiropractic in conjunction with TF assisted in adherence and functional capacity
Kingsley et al. (2010); Non RCT	29 women (9 FM and 20 HC) Age FM: 42 ± 5 years; HC: 45 ± 5 years	Duration: 12 weeks; Weekly frequency: 2; 3 series of 12 repetitions; Intensity: Initially 50% 1RM and progressively up to 85%; Exercises: Supine, extension and flexion of the knee, Leg press, low row (performed in machine) Adherence to ST: 88%	There was no group-by-time interaction for any variable. Number of active tender points, myalgic score, and FIQ score were decreased after ST in women with FM. Heart rate and natural log (Ln) high frequency (LnHF) were recovered, whereas Ln low frequency (LnLF) and LnLF/LnHF ratio were increased 20 min after acute leg resistance exercise. There were no significant effects of ST on HRV at rest or postexercise.	The ST increased strength in both groups and reduced pain and number of PT in patients with FM. The practice of ST does not change the resting HR, nor the variability of HR compared to healthy subjects.
Kingsley et al. (2011); Non RCT	23 women (9 FM and 14 HC); Age FM: 42 ± 5 years HC: 45 ± 5 years	Duration: 12 weeks; Weekly frequency: 2; 3 series of 12 repetitions; Intensity: Initially 50–60% 1RM Exercises: Supine, extension and flexion of the knee, Leg press, low row (performed in machine) Adherence to ST: 88%	Aortic and digital diastolic blood pressure (DBP) were significantly decreased and aortic and digital pulse pressures (PP) were significantly increased after acute exercise before ST. Acute resistance exercise had no effect on HR, wave reflection (augmentation index and reflection time), digital, or aortic systolic BP. ST improved muscle strength without affecting acute DBP and PP responses.	The results suggest that a leg- resistance exercise produces post-exercise diastolic hypotension and does not alter aortic systolic blood pressure and HR. In addition, vascular responses at rest and post- exercise are not altered after 12 weeks of ST in premenopausal women
Kayo et al. (2012); RCT	90 women with FM (30 ST, 30 AE and 30 CG) Age ST: 46.7 ± 6.3 years; AE: 47.7 ± 5.3 years; CG: 46.1 ± 6.4 years	Duration: 16 weeks; Weekly frequency: 3; 3 series of 10 repetitions; Exercises were not specified, however, free weights were used and the patient's body weight Adherence to ST: 73,5	All 3 groups showed improvement after the 16-week treatment compared to baseline. At the 28-week follow-up, pain reduction was similar for the AE and ST groups, but different from the control group. At the end of the treatment, 80% of subjects in the control group took pain medication, but only 46.7% in the AE and 41.4% in the ST groups. Mean FIQ total scores were lower for the AE and ST groups compared with the control group.	The ST was as effective as AE in reducing pain in relation to all study variables.
Hooten et al. (2012); RCT	72 FM (36 ST and 36 AE)	Duration: 3 weeks; Weekly frequency: 2; 1 serie of	Significant improvements in pain severity, peak Vo ₂ , strength, and	The ST was effective in reducing pain in relation to all study

Table 2 Characteristics and results of experimental studies with strength training for patients with fibromyalgia syndrome (Continued)

Study and Design	Sample	Intervention	Results	Conclusion
	Age ST 47.3 ± 10.1 years AE 45.8 ± 11.5 years	10 repetitions; Exercises: Flexion and extension of the knee and arm Adherence to ST: 94,5%	pain thresholds were observed from baseline to week 3 in the intent-to-treat analysis; however, patients in the aerobic group experienced greater gains (in peak Vo2) compared to the strength group.	variables. ST practice reduced pain significantly, but there was no difference in relation to AE.
Gavi et al. (2014); RCT	76 FM (35 ST and 36 FLEX) Age ST: 44.34 ± 7.94 years FLEX: 48.65 ± 7.60 years	Duration: 16 weeks; Weekly frequency: 2; 1 serie of 10 repetitions; Intensity: 45% 1RM Exercises: Supine, extension and flexion of the knee, elbow and shoulder, Leg press, low paddling, fly, plantar flexion Adherence to ST: 87,5%	The ST group was more effective to strength gain for all muscles and pain control after 4 and 16 weeks. The FLEX group showed higher improvements in anxiety. Both groups showed improvements in the quality of life, and there was no significant difference observed between the groups. There was no change in the HRV of the ST and FLEX groups.	There was an increase in functionality, depression, quality of life in both groups, with no statistical difference between them. There was greater reduction of pain in the ST group.
Larsson et al. (2015); RCT	130 FM (67 ST, 63 RT) Age ST: 50.81 ± 9.05 years; RT: 52.10 ± 9.78 years	Duration: 15 weeks Weekly frequency: 2 Intensity: increased progressively Exercises: The main muscle groups were worked, but exercises were not specified. Adherence to ST: 71%	Significant improvements were found for isometric knee-extension force, health status, current pain intensity, 6MWT, isometric elbow flexion force, pain disability, and pain acceptance in the ST group when compared to the CG. Differed significantly in favor of the ST group at post-treatment examinations. No significant differences between ST group and the active CG were found regarding change in self-reported questionnaires from baseline to 13–18 months.	The ST was considered a viable exercise mode for women with FM, improving muscle strength, with a significant improvement in health-related quality of life and current pain intensity, when assessed immediately after the intervention.
Palstam et al. (2016); Non RCT	67 women com FM (67 ST) Age 51 ± 9.1 years	Duration: 15 weeks; Weekly frequency: 2; Intensity: Initially 40% 1RM and progressively up to 80%; Exercises: The main muscle groups were worked, but exercises were not specified. Adherence to ST: 71%	Reduced pain disability was explained by higher pain disability at baseline together with decreased fear avoidance beliefs about physical activity. The improvements in the disability domains of recreation and social activity were explained by decreased fear avoidance beliefs about physical activity together with higher baseline values of each disability domain respectively. The improvement in occupational disability was explained by higher baseline values of occupational disability.	The ST reduces pain, inability and fear of practicing Physical exercises and increased strength and level of physical activity.
Ericsson et al. (2016); RCT	105 women (56 ST and 49 RT) Range of age 22–64 years	Duration: 15 weeks; Weekly frequency: 2; Intensity: Initially 40% 1RM and progressively up to 80%; Exercises: The main muscle groups were worked, but exercises were not specified. Adherence to ST: 71%	A higher improvement was found at the post-treatment examination for change in the ST group; as compared to change in the active CG in the MFI-20 subscale of physical fatigue. Sleep efficiency was the strongest predictor of change in the MFI-20 subscale general fatigue. Participating in resistance exercise and working fewer hours per week were independent significant predictors of change in physical fatigue.	The ST group significantly reduced general, physical and mental fatigue and improved sleep efficiency in relation to the relaxation group; depression and anxiety did not decline after the intervention
Martinsen et al. (2017); Non RCT	54 women (31 ST and 23 HC) Age ST: 49 ± 6	Duration: 15 weeks Weekly frequency: 2 Exercises: exercises were not specified.	The FIQ ratings decreased following exercise in patients with FM, suggesting an improvement of FM symptoms. Furthermore, for the	The intervention had different effects on the speed of cognitive processing during SCWT in patients with FM and

Table 2 Characteristics and results of experimental studies with strength training for patients with fibromyalgia syndrome (*Continued*)

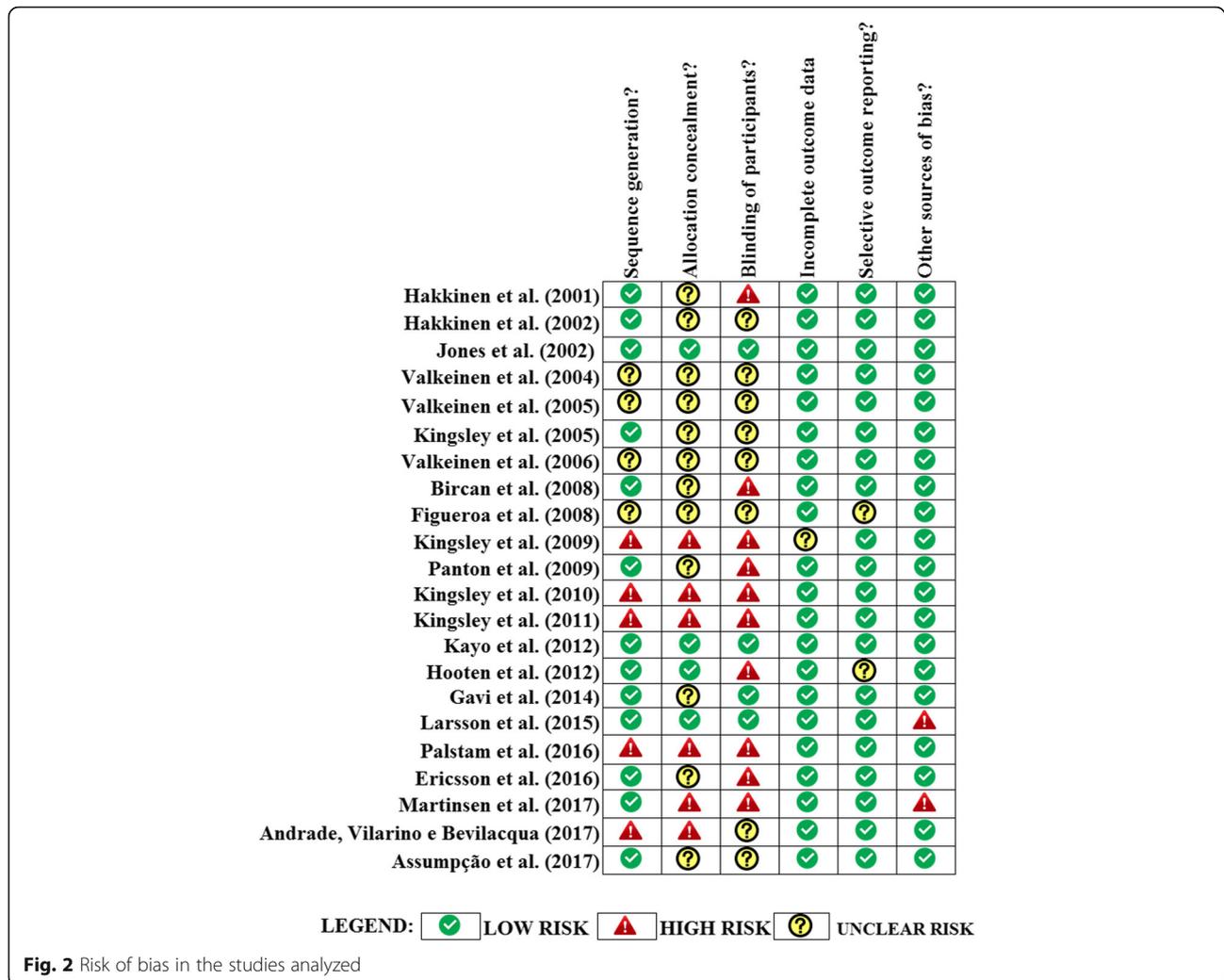
Study and Design	Sample	Intervention	Results	Conclusion
	HC: 47 ± 2	Adherence to ST: 65,5%	SF-36 PCS ratings we found a statistically significant effect of group and intervention, but no significant interaction between the factors, thus showing that exercise improved ratings of SF-36 PCS in both groups.	healthy controls. We found evidence of increased amygdala activation. In contrast, HC showed decreased RTs in incongruent and congruent stimuli. Exercise had no effect on distraction-induced analgesia or pressure pain thresholds in any of the groups but decreased the overall severity of FM symptoms.
Andrade, Vilarino e Bevilacqua (2017); Non RCT	52 FM (31 ST and 21 CG) Age ST: 54.42 ± 7.16 CG: 53.10 ± 8	Duration: 8 weeks Weekly frequency: 3 Exercises: knee extension, knee flexion, bench press, fly, adductors, low rowing, high pulley, elbow extension, lateral raise, arm curl, standing calf raise, and abdominal crunch. Adherence to ST: 81,5	After 8 weeks of intervention, significant differences were found between groups in subjective quality of sleep, sleep disturbance, daytime dysfunction, and total sleep score. The correlation analysis using Spearman's test indicated a positive relationship between the variables of pain intensity and sleep quality; when pain intensity increased in patients with fibromyalgia, sleep quality worsened.	A significant relationship was found between pain level and sleep disturbances in FM patients, and it was found that the higher the pain, the worse the sleep quality of these patients. The ST group reduced levels of sleep disturbance after 8 weeks of intervention.
Assumpção et al. (2017); RCT	53 FM (19 ST, 18 FLEX E 16 CG) Age ST: 45.7 ± 7.7 FLEX: 47.9 ± 5.3 CG: 46.9 ± 6.5	Duration: 12 weeks Weekly frequency: 2 Exercises: eight repetitions of strengthening exercises for the following muscles triceps sural, hip adductors and abductors, hip flexor, shoulder flexor and extensor, anterior and posterior deltoids, pectoralis major and rhomboids Adherence to ST: 89,5%	The ST group had the lowest depression score and; the control had the highest score of morning tiredness and stiffness, and the lowest score of vitality. In the clinical analyses, the stretching group had important improvement in quality of life for all SF-36 domains, and the strengthening group had important improvements in the impact on FM symptoms measured by the FIQ total score and in the quality of life for SF-36 domains of physical functioning, vitality, social function, role emotional and mental health.	The ST was more effective to reducing depression, while stretching exercises was better to improving quality of life, especially physical functioning and pain.

LEGEND: *FM* Fibromyalgia, *HC* Healthy Control, *RCT* Controlled and Randomized Study, *TP* Tender Points, *AE* Aerobic Group, *RT* Relaxation Therapy, *RM* 1 Maximum Repeat, *ST* Strength Training, *ST-C* Strength Training and chiropractic, *FLEX* Flexibility training, *HR* Heart Rate, *HRV* Heart Rate Variability, *CG* Control Group, *NMS* Neuro-muscular system, *SCWT* Test of colored words Stroop, *RTs* long reaction times, *FIQ* Fibromyalgia Impact Questionnaire, *SF-36* 36- Item Short Form Survey, *PCS* Physical Component, *MCS* Mental Components, *HAD* Hospital Anxiety and Depression Score, *6MWT* 6 min walking test, *PGIC* patient global impression of change, *VAS* Visual Analogue Scale, *MFI-20* Multidimensional Fatigue Inventory, *CSA* cross-sectional area, *QF* quadriceps femoris, *LF* low-frequency, *GH* growth hormone, *HAQ* Health Assessment Questionnaire, *EMG* Surface electromyographic, *Hfnu* normalized high-frequency, *Lfnu* normalized low-frequency, *RTs* reaction times

has favorable results, such as reducing physical and psychological symptoms. However, there are still gaps that need to be investigated.

Concerning the ST sessions, it was observed that there is no specific training protocol for patients with FM; thus, the researchers developed their own protocol. Jones et al. [45] submitted the patients to a series of four to five repetitions, progressively increasing the number of repetitions up to 12. This protocol was similar to that used by Bircan et al. [42], who instructed patients to perform a series of four repetitions and progressively increased the repetitions by up to 12. Kingsley et al. [28] and Figueroa et al. [49] also submitted the patients to a series in each exercise;

however, from the beginning of the intervention, the patients were instructed to perform from 8 to 12 repetitions. As the first studies analyzed were published in 2001 and 2002, and at that time there was little knowledge about the development of the disease and the effects of ST on the patients, those first studies chose to use low load and series. On the basis of the results of the earlier studies, more studies were performed and chose to use more series with more repetitions from the beginning [24, 27, 44, 48]. Despite some differences in the protocols, the intensity of the exercises increased gradually. In some studies, the intensity reached 80% of 1RM at the end of the intervention [25, 27]. Another issue concerns weekly



frequency, but this differed slightly between 2 and 3 weekly sessions. Despite the differences in the protocols, it was observed that, in general, the studies followed the recommendations of the American College of Sports Medicine for beginners in ST.

With regard to the main symptoms, there was a greater interest in pain, strength, quality of life, HRV, and depression. Pain is the main symptom of FM and is associated with other symptoms such as depression, sleep disorders, and poor quality of life [24, 56]; thus, finding treatments that improve these symptoms are of crucial clinical relevance for patients. The results of the present review demonstrate that the pain of patients with FM is significantly reduced by the ST intervention. Valkeinen et al. [53] evaluated 23 women with FM, of whom 13 were submitted to 2 ST sessions for 21 weeks and 10 were part of the control group. At the end of the 21 weeks of intervention, significant improvement in pain was observed. Other studies examined the effect of shorter periods of ST, and found that pain can be

reduced in a short time. Hooten et al. [30] analyzed the effect of 3-week ST on pain. Participants performed 2 weekly sessions, consisting of a series of 10 repetitions of knee and elbow flexion and extension exercises. At the end of the study, a significant reduction of pain was observed. This result is interesting for health professionals and for patients with FM, because it demonstrates that ST can help reduce symptoms in a few weeks and with few exercises.

Studies indicate that patients with FM have less strength and reduced functional capacity compared with healthy persons of the same age and without the disease [57]. The reduced muscle strength of patients with FM may be related to pain; because of pain, it is common for patients to avoid making physical efforts. However, studies that aimed to verify the responses of patients with FM after muscular effort showed positive results. In studies that applied ST, strength and hypertrophy were similar between patients with and those without the disease.

The first studies in this sense were those of Hakkinen et al. [38], Hakkinen et al. [51], Valkeinen et al. [41] and Valkeinen et al. [52]. The first 2 studies analyzed the effect of 21-week ST in patients with FM, and compared the results with those of healthy persons. From the results of these studies, it can be observed that there was an increase of force, activation, and hypertrophy in the ST group and in controls. Hakkinen et al. [51] verified an increase of 18% in the muscular strength of patients with FM, and of 22% in the control group, concluding that the neuromuscular adaptations derived from ST are similar between patients with FM and healthy persons. Reinforcing this result, Valkeinen et al. [41] observed a significant increase of the strength in the extension and flexion of the knee in patients with FM [33% and 20%, respectively], whereas in the control group the gains were 12% and 17%, respectively. Valkeinen et al. [52] that analyzed strength found that after 21 weeks of ST, patients with FM had a 36% increase in isometric force and 33% in concentric force. In addition, the authors verified a 5% increase in the cross-sectional area of the thigh and increased activation by 57%. After analyzing the results, the authors concluded that ST is safe for patients with FM and that the patients can undergo training with higher intensities.

Another variable that was investigated in the studies was the HRV. Some authors suggested that FM occurs because of dysregulation of the central nervous system [6, 8], causing an autonomic dysfunction that induces the appearance of some symptoms such as fatigue and anxiety. Figueroa et al. [49] verified the heart rate behavior of patients with FM who also had autonomic dysfunction. The researchers subjected the patients to 16 weeks of ST and verified improvements in HRV, parasympathetic activity, and pain reduction. Kingsley et al. [27] compared the effects of 12 weeks of ST on patients with FM and healthy women, in terms of various symptoms such as pain, number of tender points, impact of FM on quality of life, and HRV. The results showed an increase in strength in both groups, besides the reduction of pain and tender points in patients with FM; however, in terms of the behavior of HRV, no significant difference was observed between patients with FM and the healthy group. In contrast, in the study of Kingsley et al. [43] that aimed to verify the autonomic modulation of patients with FM after a ST session, the results demonstrated that patients with FM had a lower sympathetic response and greater vagal modulation, without altering the baroreflex sensitivity, a response different from that presented by the control group. Concerning a possible autonomic dysfunction in patients with FM, further studies need to be carried out in order to reach a conclusion.

Other symptoms investigated were quality of life, depression, and sleep disturbance. As quality of life is a

variable that is directly related to other symptoms, the improvements observed in the other symptoms suggest that the quality of life could also be expected to increase. In the study of Gavi et al. [29], significant improvements in pain, functionality, quality of life, and depression were found after 16 weeks of ST. Similar results were found by Larsson et al. [54] and Palstam et al. [55]. In the first study, there was a reduction in pain and an increase in strength and quality of life. In the second study, in addition to the results seen in previous studies, the researchers noticed a reduction in the fear of performing exercises. With regard to sleep disturbance, some studies found a reduction after ST intervention [24, 25]. In addition, sleep quality correlated with pain, with patients having less pain experiencing less sleep disorders [24].

With the new possibility of using ST as an alternative treatment for patients with FM, some researchers began to compare the effects of ST with those of other physical exercise interventions. In the study of Bircan et al. [42], 13 women with FM were submitted to aerobic exercise and 13 were submitted to ST. The researchers found that both interventions have benefits for patients, including reduction of pain, fatigue, sleep disorders, and depression, and improvement of aerobic capacity. However, no significant improvements in anxiety were observed in either group. In the studies by Kayo et al. [48] and Hooten et al. [30], the effects of ST were also compared with those of aerobic exercise. It was noted that the 2 interventions presented similar results, particularly in reducing the pain of patients. In addition, other studies compared ST with relaxation or flexibility exercises. Assumpção et al. [40] verified the effects of ST and flexibility exercises after 12 weeks of intervention. The results demonstrated that ST is more effective in reducing depression, whereas flexibility exercises are better at improving the quality of life, especially physical function and pain. Gavi et al. [29] found similar results: ST and flexibility training were effective for reducing symptoms; however, the best results in terms of pain were found in the ST group. The study of Jones et al. [45] also compared ST and flexibility training, and verified that both interventions are effective; however, the most significant results were found in the ST group. Lorena et al. [58] performed a systematic review on the effects of stretching in patients with FM, and reported the importance of this intervention in improving the physical and mental aspects of patients. Nevertheless, they emphasized the need for studies with greater methodological rigor. The same can be emphasized in the present review: the positive effect of ST in patients with FM is visible, but it is necessary to carry out more studies with greater methodological rigor to address possible gaps.

Another interesting result is about adherence to treatments. It is known that patients with FM have difficulties

adhering to the practice of physical exercise; however, few studies reported the adherence of patients to the interventions [59, 60]. In the present review, the mean adherence percentage was 84%, a result similar to that of the study by Sanz-Baños et al. [59] in patients undergoing aerobic exercises [adherence percentage 87.2%]. This result is a further indication that ST can be used as part of the treatment for patients with FM, because in addition to improving the symptoms, the patients show high adherence to the intervention.

Concerning the strengths and limitations of the study, we were able to verify through a broad literature review that ST improves the symptoms of patients with FM; however, some studies presented a high risk of bias and further studies are needed to consolidate the obtained results. In addition, future reviews including the gray literature are warranted in order to identify other studies on the subject.

Conclusion

In conclusion, ST had positive effects on physical and psychological symptoms, in terms of reducing pain, the number of tender points, and depression, and improving muscle strength, sleep quality, functional capacity, and quality of life. Intervention protocols should start at low intensity (40% of 1RM) and gradually increase the intensity. ST should be performed 2 or 3 times a week to exercise the main muscle groups. The current studies showed that ST is a safe and effective method of improving the major symptoms of FM and can be used to treat patients with this condition.

Additional file

Additional file 1: Search strategies at PubMed. (PDF 94 kb)

Abbreviations

1RM: One maximum repetition; FM: Fibromyalgia; HRV: Heart Rate Variability; PE: Physical Activity; ST: Strength Training

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Authors' contributions

AA, S.R.A.K, S.S.M, T.L.A.P drafted the manuscript. S.R.A.K, V.T.G., S.S.M., carried out the analysis. All authors discussed the results, commented on the manuscript and approved the final draft of the manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

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Competing interests

Alexandro Andrade, Ricardo de Azevedo Klumb Steffens, Sofia Mendes Sieczkowska, Leonardo Alexandre Peyré Tartaruga and Guilherme Torres Vilarino declare that they have no conflict of interest.

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Author details

¹Health and Sports Science Center, CEFID / Santa Catarina State University – UDESC, Florianópolis, SC, Brazil. ²Laboratory of Sports and Exercise Psychology - LAPE, Florianópolis, SC, Brazil. ³Regional University of Blumenau - FURB, Blumenau, SC, Brazil. ⁴Human Movement Sciences and Pneumological Sciences, UFRGS- Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil. ⁵Research Laboratory of Exercise – LAPEX, Porto Alegre, RS, Brazil.

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