Arthritis & Rheumatism
ARTHRITIS CARE & RESEARCH 47:22–28, 2002
DOI 10.1002/art1.10180

ORIGINAL ARTICLE

The Effects of Progressive Strength Training and Aerobic Exercise on Muscle Strength and Cardiovascular Fitness in Women With Fibromyalgia: A Pilot Study

DANIEL S. ROOKS,[1] CAROLINE B. SILVERMAN,[2] AND FRED G. KANTROWITZ[1]

Objective. **To determine the safety, feasibility and consequences of a program of progressive strength training and cardiovascular exercise in women with fibromyalgia syndrome (FMS).**
Methods. **Fifteen women with confirmed FMS were monitored for injury and exercise compliance, and assessed for muscle strength (1-repetition maximum technique), cardiovascular endurance (6-minute walk test), and functional status (Fibromyalgia Impact Questionnaire [FIQ]) before and after a 20-week exercise intervention.**
Results. **Zero injuries and an 81% compliance rate occurred during training. Improvement was seen in muscle strength of the lower (191 ± 75 to 265 ± 67 pounds; $P < 0.001$) and upper (61 ± 18 to 76 ± 18 pounds; $P < 0.001$) body, 6-minute walk distance (530 ± 80 to 629 ± 74 meters; $P < 0.001$), and in FIQ score (44 ± 9 to 32 ± 14; $P < 0.01$).**
Conclusion. **A program of progressive strength training and cardiovascular exercise can be safe, well tolerated, and effective at improving muscle strength, cardiovascular endurance and functional status in women with FMS without exacerbating symptoms. This program may also contribute to a reduction in the severity of several symptoms.**

KEY WORDS. Fibromyalgia; Strength training; Aerobic exercise; Women; Exercise therapy.

INTRODUCTION

Fibromyalgia syndrome (FMS) is a complex, noninflammatory pain syndrome characterized by total body pain, fatigue, and dysfunctional sleep patterns, and is associated with several comorbidities including, depression, anxiety, irritable bowel syndrome, irritable bladder syndrome, Raynaud's syndrome, and neuralgias (1,2). FMS is the second most common rheumatologic disorder in the United States, affecting approximately 4–6 million Americans (3,4). Currently, FMS is poorly understood, having no known etiology or cure. Symptoms demonstrate an inconsistent and frequently unpredictable pattern of severity and a resistance to standard approaches to care. Current treatment centers on the use of pharmacotherapy and self-management techniques (5,6).

It is widely accepted that exercise is beneficial in the self-management of FMS. Current recommendations include participation in aerobic and flexibility training (7,8). The focus on cardiovascular exercise reflects early studies that reported below-average levels of cardiovascular fitness in patients with FMS (9,10). However, even though a lower level of muscle strength has been reported in the FMS population (11–13), most studies involving exercise and patients with FMS have not included strength training as part of the intervention. At least one reason has been a concern about an increased risk for subject injury and exacerbation of symptoms. These ideas stem from a theory that FMS is associated with abnormal muscle tissue function (14,15). As a result, strength training has not been well examined as part of an exercise program for the patient with FMS. In the few published studies that include strength training as part of an intervention, few data have

Data presented at the 64th Annual Scientific Meeting of the American College of Rheumatology and Association of Rheumatology Health Professionals, Philadelphia, PA, October 1999.
Supported in part by the New England Baptist Bone and Joint Institute Laboratory and the Dedham Health and Athletic Complex.
[1]Daniel S. Rooks, ScD, Fred G. Kantrowitz, MD: New England Baptist Bone and Joint Institute, New England Baptist Hospital, Beth Israel Deaconess Medical Center, and Harvard Medical School, Boston, MA; [2]Caroline B. Silverman, BA, Beth Israel Deaconess Medical Center, Boston, MA.
Address correspondence to Daniel S. Rooks, ScD, Bone and Joint Institute, Harvard Institute of Medicine, 4 Blackfan Circle, Boston, MA 02115. E-mail: drooks@caregroup.harvard.edu.
Submitted for publication, November 29, 2000; accepted in revised form August 7, 2001.

been reported on changes in muscle strength, and most do not clearly describe the exercise program. Currently, there remains a lack of understanding about appropriate use of exercise in general, and strength training in particular, in patients with FMS. Therefore, we performed a prospective study to answer the following questions: 1) Can an exercise program combining strength training, cardiovascular and flexibility exercise improve the fitness levels of women with FMS without exacerbating symptoms or causing musculoskeletal injury? And, 2) how compliant will this population be with a long-term exercise program of this type?

SUBJECTS AND METHODS

Subjects. Twenty-four women with a confirmed diagnosis of fibromyalgia were recruited to participate in this study. Subjects who met the American College of Rheumatology (ACR) criteria for FMS (16) were recruited primarily through physician referral, with the majority coming from a single rheumatologist (FGK). Each potential volunteer was screened by telephone to ensure appropriateness for the study. Volunteers were queried about their participation in regular physical activity, the amount, type, and intensity of the activity, and whether exercise had ever exacerbated their FMS symptoms. The revised Physical Activity Readiness Questionnaire (17), a validated series of 7 questions that aim to identify persons at risk for adverse events while exercising, particularly cardiovascular events, was also administered. Finally subjects were asked about their medical history using a modified version of the Older Americans Resources and Services medical history questionnaire (18), that had been used previously by the authors (19,20). To participate, volunteers needed written confirmation of a diagnosis of FMS based on ACR criteria (16), a history of moderate to no physical activity in the previous year, transportation to the exercise site, and medical clearance to exercise. Each volunteer's primary care physician confirmed the diagnosis of FMS and provided written medical clearance for participation in an exercise intervention.

We piloted a physician approval procedure to expedite written confirmation of a diagnosis of FMS and to obtain medical clearance for participants' involvement in an exercise program. A letter explaining the study and subject participation requirements, and a 2-page clearance form were mailed to the office of each volunteer's primary care physician. The form listed 7 questions in a yes/no format to confirm the diagnosis of FMS, and identify the presence of health-related risk factors that would exclude a patient from participating in the study. The form also requested a list of current medications and any physical limitations or concerns. The form was signed by the primary care physician and returned via fax. This approach enabled us to confirm the diagnosis of FMS and obtain clearance for participation in the exercise intervention faster than when there was no form and we requested a letter clearing the volunteer for participation. Physician clearance was received from 100% of the requests, and 22 of 24 responses were received within 2 weeks. All subjects gave written informed consent prior to participation. The study was approved by The Institutional Review Board of the New England Baptist Hospital.

Testing. Outcome measures were assessed through a combination of performance-based and self-report formats. All subjects were evaluated twice—at baseline, and after completion of the 20-week exercise intervention. Preintervention testing was performed within 2 weeks of starting exercise, while posttesting was completed within 4 days of the last exercise session.

Muscle strength was assessed in the upper and lower body using a 1-repetition maximum technique (1-RM) (20). Although not previously reported in persons with FMS, this technique has been safely used in older adult populations (20–22), including frail older adults (23) and cardiac patients (24,25). The test requires the subject to perform repeated single repetitions of a particular anatomic motion, separated by periods of rest. Resistance is systematically added after the successful completion of a repetition, until the person's maximum voluntary muscle force cannot move the resistance through the full range of motion (20,26). The greatest weight a person can move through a full range of motion is recorded as the "1-repetition maximum." Prior to any physical effort, subjects were shown proper technique of the chest press and leg press, and were given specific instructions on how to perform the test and when to stop. Subjects warmed up by performing 6 to 8 repetitions with light resistance on the machines. Subjects were instructed to stop an effort when they felt they "were not able to safely push against the weight" or when a maximal voluntary effort could not complete a repetition (i.e., momentary failure). All tests were performed on Life Fitness Leg Press and Chest Press machines (Life Fitness, Franklin Park, IL). The 1-RM testing technique had high reproducibility within the cohort ($R = 0.95$). The 1-RM test was performed after the 6-minute walk to ensure proper body warm-up and to reduce the chance of muscle strain.

The 6-minute walk test was used to assess cardiovascular fitness and mobility endurance (27). Subjects were instructed to walk as far as they could in 6 minutes. They could stop and rest or terminate the rest at their own discretion if they experienced pain, shortness of breath, or other complication. A 5-minute rest period was given prior to the start of testing during which the resting heart rate was measured by radial artery palpation. Measurement of heart rate was repeated at 0, 1, 2, and 3 minutes post completion of the 6-minute walk. The distance walked (in meters) and heart rate (in beats per minute) at each time point are reported.

The Fibromyalgia Impact Questionnaire (FIQ) is a validated instrument that assesses physical function (instrumental activities of daily living [IADL]), general well-being and FMS-related symptoms (pain, fatigue, morning tiredness, stiffness, anxiety, and depression) (28). Scoring uses a Likert scale to document frequency of IADL performance, number of days in a week the person "felt good," and a series of visual analog scales to quantify the effect of FMS symptoms on job performance, severity of pain, gen-

eral and morning tiredness, stiffness, anxiety and depression. A higher score indicates a greater level of difficulty or illness, and a reduction in score an improvement in functional status.

Training protocol. The intervention was designed to gradually increase the volume and intensity of exercise a person performed, to involve all major muscle groups of the body, and to include all 3 aspects of fitness—cardiovascular endurance, muscle strength, and joint flexibility. The intervention began with a low volume of exercise performed at a low intensity, because of the expected lower levels of cardiovascular fitness (9) and muscle strength (11,12) reported in women with FMS, and the lower threshold for postexercise muscle pain and fatigue seen in this population (29). Participants exercised for 60 minutes per session, 3 times per week for 20 weeks.

The intervention was composed of 2 phases of exercise. The first phase (4 weeks) was performed in a pool, and focused on active range of motion of the body's major joints. Movements were controlled single-joint motions. The second phase (16 weeks) involved land-based exercises for improving cardiovascular endurance, muscle strength, and joint range of motion. Each exercise session was divided into 3 sections—cardiovascular, strength training, and flexibility—and was always performed in the same order. Cardiovascular exercises incorporated walking on a treadmill (Life Fitness), an elliptical device (Precor, Bothell, WA), and walking on a track. Strength training exercises included static contractions for pelvic and lumbar spine stabilization, and dynamic movement of large muscles and multijoint actions: hip flexion/extension, knee extension/flexion, ankle plantar/dorsiflexion, shoulder flexion, extension, abduction and horizontal adduction and abduction, elbow flexion and extension, and trunk flexion and rotation. Strength training exercises were performed using a combination of machines (Life Fitness), hand weights, and body weight. Subjects began with resistance levels they could do easily, and progressed in an 8-10-12-12 repetition format when appropriate. Flexibility was developed using a complete range of motion during strength training movements, traditional stretches, and a flexibility device (Precor). The land-based exercise program was revised after 3 months to prevent boredom and reduce the chance of dropout.

Statistical analysis. All analyses were performed with JMP statistical software (30) using data from all subjects who were retested after completion of the 20-week intervention, regardless of how often they attended exercise sessions. Data were assessed for normality using the Shapiro-Wilk W test. A paired *t*-test was used for analysis because the data for within-subject changes over time of the 4 outcome measures were normal ($P > 0.50$). All *t*-tests were 2-tailed. Statistical significance was set at $P < 0.05$.

Table 1. Subject demographics

Characteristic	n	%
Female	15	100
Married	10	67
Single	1	7
Divorced	4	27
Education		
Postgraduate	8	53
College	3	20
Some college	4	27
Currently working outside of home	9	60
Collecting disability	3	20
Age (Mean ± SD)	44.9 ± 8.8 years	
Number of medications	3.1 ± 2.1	
Antidepressants	9	60
Benzodiazapines	5	33
NSAIDS	5	33
Cyclobenzaprine	5	33
Non-FMS medications	12	80

FMS = fibromyalgia syndrome; NSAIDS = nonsteroidal antiinflammatory drugs.

RESULTS

Subjects. Thirty women met the inclusion criteria, 24 enrolled, and 15 completed the study. Of the 6 women who did not participate initially, 3 were unable to meet the time requirement of 3 times per week for 20 weeks, 2 had a conflict with work hours, and 1 lived too far away from the exercise site. Nine women dropped out of the study at various times during the 20-week period. Reasons for drop-out included time conflicts with work and family, distance traveled to the exercise site, and non–FMS-related illness. Most of the 15 participants who completed the intervention were married, working, approximately 45 years old, had a college education, had experience with exercise prior to the study, and were currently taking an average of 3 medications each (Table 1). The majority of the patients experienced their pain in the neck, upper and lower back, hips, and lower extremities (Table 2). The

Table 2. Subject medical history at baseline (n = 15)

Areas of pain	n	%
Head and neck	15	100
Lumbar	14	93
Leg and foot	12	79
Thoracic	11	71
Hip	11	71
Knee	11	71
Shoulder	7	47
Elbow and hand	7	47
Comorbidities		
Depression	7	47
Arthritis	5	33
Stomach problems	4	27
Thyroid problems	3	20
Circulation problems	3	20
High blood pressure	3	20
Osteoporosis	2	13

Table 3. Primary outcome measure performance at baseline and postexercise (n = 15)

Outcome measure	Baseline (Mean ± SD)	Postexercise (Mean ± SD)	Difference (Mean ± SD)	*P*
Chest press (pounds)	61 ± 18	76 ± 18	15 ± 13	0.001
Leg press (pounds)	191 ± 75	265 ± 67	74 ± 57	0.0002
6-minute walk (meters)	530 ± 80	629 ± 73	99 ± 87	0.001
Heart rate				
Resting	81 ± 16	84 ± 16		>0.05
1 minute after walk	103 ± 23	104 ± 22		>0.05
2 minutes after walk	91 ± 15	90 ± 19		>0.05
3 minutes after walk	87 ± 15	86 ± 16		>0.05

primary comorbidity in the study group, reported by 7 of the 15, was clinical depression. No difference in baseline measurements was seen between the subjects who completed the intervention and those who dropped out.

Safety and compliance. There were no injuries during the exercise sessions, and subjects demonstrated a high rate of compliance throughout the 20-week intervention period. Five subjects reported temporary muscle soreness after the first week of exercise in the water, and then again during the first week on land. However, none of those reporting soreness experienced a flare in symptoms during these weeks of exercise. One subject reported soreness in the shoulder and knee for more than 48 hours after completing the baseline testing. She was evaluated by an orthopedic surgeon and did not require medical treatment. Specific attention was given to this subject to modify the training intensity, as she requested, and no further incident was reported. This subject dropped out of the study during week 12. Exercise program compliance was determined by the number of exercise sessions attended, divided by the number of sessions held. Subjects who completed the study attended an average of 81% of the exercise sessions. Program evaluations and followup discussions were held at the completion of the study to learn more about program acceptance, unmet needs, and future study intervention design. Social interaction, group camaraderie, physical benefits (improved energy, less morning stiffness, ability to return to activities of daily life, e.g., shopping, riding bicycle with children, preparing dinner for family), and fun were the most important aspects of the program to the participants.

Fitness. All subjects who completed the intervention exhibited improved muscle strength and cardiovascular fitness. At baseline, strength values for the lower extremity, as measured by the 1-RM leg press, ranged from 80–395 pounds (mean 191 pounds). Upper body strength, as measured by the 1-RM chest press, ranged from 25–95 pounds (mean 59 pounds). After the intervention, mean strength increased by 39% (74 ± 57 pounds mean strength; $P = 0.001$; 95% confidence interval [95% CI] 42–105) in the lower extremity, and by 27% (16 pounds mean strength; $P = 0.001$; 95% CI 9–23) in the upper body. Fourteen of the 15 subjects improved their lower extremity strength by 10–160 pounds. The one subject who did not improve in lower extremity strength (395 pounds at baseline–375 pounds at completion) attended the fewest sessions (53%) and had a much higher baseline value than the rest of the group (395 pounds versus 176 pounds). Twelve of 15 women improved their upper body strength 5–40 pounds. Of the 3 who did not gain in strength, 2 had no change, and 1 had a score 5 pounds less than baseline. Strength improved throughout the 20-week intervention as reflected by the continuous progression in the amount of resistance used in training.

Six-minute walk distance improved 20% (99 ± 87 meters; $P = 0.001$, 95% CI 51–147) in the group. Of the 13 subjects who increased their walking distance, 10 walked >80 meters more, with 7 walking >100 meters farther than baseline efforts. These gains were observed with no change in heart rate (Table 3), suggesting similar effort was made during both baseline and postexercise testing.

Symptoms. FIQ scores were used to determine changes in symptom severity and overall functional status in our sample (Table 4). Total FIQ score and severity of stiffness, anxiety, pain, fatigue, morning tiredness, and depression improved significantly ($P < 0.05$) in the group. These findings suggest FMS-related symptoms did not worsen as a result of the exercise program, but in fact improved over the intervention period. Changes in total FIQ score (mean ± SD 12.5 ± 13.7 units; $P < 0.01$, 95% CI 5–20) indicate that the exercise program contributed to the improved functional status of our sample.

DISCUSSION

Women with FMS safely improved their muscle strength and cardiovascular fitness through a program of progressive strength training, cardiovascular and flexibility exercise. This program did not exacerbate FMS-related symptoms nor did it result in musculoskeletal injuries. In fact, participants reported improvement in functional status and reduction in FMS-related symptoms. Throughout the 20-week intervention, the participants who completed the study (15 of 24, 63%) had high compliance, attending 81% of exercise sessions. These findings demonstrate that an exercise program that includes strength training activities can be safe, feasible, and beneficial for persons with FMS, specifically in the areas of improving muscle strength, walking distance, functional status, and symptom severity.

Significant improvement in muscle strength is the key

Table 4. Fibromyalgia Impact Questionnaire (FIQ) results at baseline and postexercise (n = 15)

Scale	Baseline (Mean ± SD)	Postexercise (Mean ± SD)	*P*
Total FIQ score	44.3 ± 9.0	31.8 ± 13.5	0.002
Physical impairment	3.7 ± 0.7	3.3 ± 0.7	0.18
Felt good	6.0 ± 1.8	4.8 ± 2.0	0.03
Missed work	1.6 ± 1.8	2.1 ± 2.4	0.19
Symptoms interfered w/job	5.0 ± 2.5	3.6 ± 2.6	0.04
Pain	6.1 ± 1.7	4.8 ± 2.5	0.03
Fatigue	7.3 ± 1.8	5.3 ± 2.6	0.02
Rested	7.7 ± 1.9	5.5 ± 2.5	0.02
Stiffness	7.3 ± 1.5	4.8 ± 2.3	0.008
Anxiety	6.1 ± 2.4	4.2 ± 2.9	0.008
Depression	4.9 ± 2.3	3.2 ± 2.4	0.03

finding of this study. Numerous studies examining the muscles of patients with FMS have reported inconsistent findings with regard to histologic and biochemical characteristics (14,31–33), and force and fatigue patterns (12–14,34,35), providing insufficient evidence of an organic reason for the reduced level of muscle strength. Therefore, it can be assumed that with the proper stimulus, strength improvements can be expected. However to date, few exercise intervention studies involving patients with FMS have examined strength as an outcome or included strength training exercises in the intervention. Our findings agree with those of Bailey and colleagues (36), who reported an increase in upper body strength in a sample of patients with FMS. A comparison between their results and those of this study is not possible because of the difference in outcome measure (1-RM versus Canadian Standardized Test of Fitness). The present findings demonstrate that women with FMS can regularly perform submaximal exercise at a sufficient intensity to stimulate physiologic adaptation in muscle strength. Keys to this observed change are the high compliance rate and exercise progression.

Most FMS-related exercise studies have focused almost exclusively on the cardiovascular (aerobic) component of fitness. This is due in part to early reports of low cardiorespiratory fitness (9,10), presence of pathologic changes in muscle that include altered levels of high-energy phosphates and mitochondria (14), documented benefits from cardiovascular exercise interventions (37), and the observation that highly aerobically fit individuals were resistant to induced FMS-like sleep dysfunction (38). Baseline values of 6-minute walk distance of the participants in our study were similar to (39,40) and greater than (41) those in other intervention studies. The mean improvement of 99 meters seen in our participants was greater than that reported by others with similar groups at baseline. Bennett et al (39) reported an improvement of 55 meters after completing a 6-month multidimensional treatment program, of which exercise training was part. Burckhardt et al (40) used exercise in 1 of 3 arms (education, education plus exercise, waiting list control) and reported a mean increase of 5 meters in the group who completed 6 weeks of education plus exercise. Gowans et al (41), using a 6-week intervention of education and exercise, reported an increase of 72 meters in the intervention group and 22 meters in the control group. Their sample had a lower performance level at baseline, which possibly allowed for greater improvement in the shorter time period. The differences seen between our findings and those of others are probably due to the longer duration of our intervention, the intensity of exercise performed on a regular basis and the concomitant increase in muscle strength.

The intensity of exercise is a critical determinant of the magnitude of its effect. In this study, we controlled the level of effort by holding people back during the first 5 weeks, and then adjusted the level of resistance on strength training exercises and the speed of walking to their level of difficulty. Subjects knew they could always return to a lower level of intensity and were not afraid to try to increase. This "self-paced" approach, which is based on the person's decision to increase, decrease, or maintain a level of exertion for an exercise during each exercise session, has been successful in other musculoskeletally impaired populations (19,20). Because of the increased risk of exercise causing an exacerbation of symptoms and prolonged pain (29), we speculate that in previous studies caution was used in determining the appropriate level of exercise intensity, which resulted in interventions that were below the threshold needed to precipitate physiologic changes. The absence of injury and magnitude of changes we observed in muscle strength performance, 6-minute walk distance, and symptom severity suggest that our intervention was appropriate for the heterogeneous levels of fitness seen in patients with FMS to bring about physiologic changes while not overtraining.

Compliance is critical to the success of an exercise intervention. Participants who completed our study attended 81% of the exercise sessions over the 20-week intervention period. This level of compliance was similar to the 86% reported by Gowans et al (41) for a 12-week education and exercise intervention. Comparison with other studies examining exercise interventions in the FMS population is not possible since compliance rates have not been customarily reported (36,40,42–44). Our compliance rate is a key reason for the improvements seen in this study, and reflects a combination of the positive experience people had at the exercise sessions, the perceived efficacy of the exercise program throughout the intervention period, the benefit of the group dynamics, and commitment of the subjects to the project and themselves.

Sixty-three percent of subjects completed the study (15 of 24 subjects). This attrition rate of 37% is similar to that reported in other group interventions for FMS of shorter (36,42) or similar length (39,43).

Several limitations exist in our study. First, the sample size is small. Although this limits the ability to generalize the findings, the consistency and magnitude of a positive effect on muscle strength, cardiovascular fitness and symptoms, and the high compliance rate we observed in the group suggest the findings are real. Second, our study lacked a control group for comparison. Improvements in upper and lower body strength and 6-minute walk distance documented in this study could be due to changes in effort. Patients with FMS have been reported to exert below-maximum effort on performance measures of muscle strength and cardiovascular fitness (11–13). In our study, this could mean that all subjects (because all improved in 1 or more measurements) did not give maximal effort on each test at baseline, but did at followup testing. This is highly unlikely. To assess effort (i.e., intensity) during the 6-minute walk test, we used posttest heart rate (Table 3), an objective measure that cannot be consciously controlled, rather than rated perceived exertion scores, a self-reported measure (45). Our finding of similar posttest heart rates suggests similar levels of effort during both testing sessions. Muscle strength testing is more difficult to evaluate because subjects repeatedly progressed until momentary failure, and there are no reports of 1-RM testing values in the FMS literature for comparison. There are precedents in the literature for this uncontrolled, simple approach (46). However, the next step in maximizing the exercise program for patients with FMS is the performance of randomized, controlled trials.

In summary, the data from this pilot study indicate that women with FMS can safely participate in and benefit from a program of moderate-intensity strength training, cardiovascular, and range of motion exercises progressed at a slow to moderate rate of intensity. Moreover, women with FMS can exercise at a sufficient intensity to precipitate fitness changes, specifically muscle strength and cardiovascular fitness, without causing an exacerbation of symptoms or increased risk of musculoskeletal injury. We also found a positive effect of this exercise program on several key FMS-related symptoms: pain, fatigue, sleep, stiffness, anxiety, and depression. With the growing list of health benefits from exercise in general, and strength training in particular, these data support the inclusion of strength training as part of the recommended regimen of exercise for women with FMS. However, because these data are from a nonrandomized, uncontrolled study with a small sample, further work on exercise selection, intensity, volume, and progression needs to be performed in a randomized, controlled trial design before appropriate strength training guidelines can be developed for patients with FMS.

ACKNOWLEDGMENTS

We are grateful to the following individuals for their contribution to this work: Lloyd and Roberta Gainsboro for their support of the project and the use of the fitness center to perform the exercise program; Guy Caracciolo, Denise Blakely and Dodi Herk for their assistance with the exercise sessions; Jeffrey N. Katz MD, MS, of Brigham and Women's Hospital and Robert Parker, ScD, of Beth Israel Deaconess Medical Center for their review of the manuscript, and Jane Manwaring for her assistance with its preparation. We are especially grateful to the participants in this study who demonstrated courage and determination to overcome personal fears and uncertainty in participating in strength training activities.

REFERENCES

1. Wolfe F, Anderson J, Harkness D, Bennett RM, Caro XJ, Goldenberg DL, et al. Health status and disease severity in fibromyalgia: results of a six-center longitudinal study. Arthritis Rheum 1997;40:1571–9.
2. Reifenberger DH, Amundson LH. Fibromyalgia syndrome: a review. Am Fam Physician 1996;53:1698–704.
3. Wolfe F, Anderson J, Harkness D, Bennett RM, Caro XJ, Goldenberg DL, et al. A prospective, longitudinal, multicenter study of service utilization and costs in fibromyalgia. Arthritis Rheum 1997;40:1560–70.
4. Wilke WS. Fibromyalgia: recognizing and addressing the multiple interrelated factors. Postgrad Med 1996;100:153–70.
5. Simms RW. Controlled trials of therapy in fibromyalgia syndrome. Bailliere's Clin Rheumatol 1994;8:917–34.
6. Sandstrom MJ, Keefe FJ. Self-management of fibromyalgia: the role of formal coping skills training and physical exercise training programs. Arthritis Care Res 1998;11:432–47.
7. Klug GA, McAuley E, Clark SR. Factors influencing the development and maintenance of aerobic fitness: lessons applicable to the fibrositis syndrome. J Rheumatol 1989;16 Suppl 19:30–9.
8. Clark SR. Prescribing exercise for fibromyalgia patients. Arthritis Care Res 1994;7:221–5.
9. Bennett RM, Clark SR, Goldberg L, Nelson D, Bonafede RP, Porter J, et al. Aerobic fitness in patients with fibrositis: a controlled study of respiratory gas exchange and ^{133}xenon clearance from exercising muscle. Arthritis Rheum 1989;32:454–60.
10. McCain GA, Bell DA, Mai FM, Halliday PD. A controlled study of the effects of a supervised cardiovascular fitness training program on the manifestations of primary fibromyalgia. Arthritis Rheum 1988;31:1135–41.
11. Lindh MH, Johansson GA, Hedberg M, Grimby G. Studies on maximal voluntary muscle contraction in patients with fibromyalgia. Arch Phys Med Rehabil 1994;75:1217–22.
12. Nørregaard J, Bülow PM, Vestergaard-Poulsen P, Thomsen C, Danneskiold-Samsøe B. Muscle strength, voluntary activation and cross-sectional muscle area in patients with fibromyalgia. Br J Rheumatol 1995;34:925–31.
13. Nørregaard J, Bülow PM, Lykkegaard JJ, Mehlsen J, Danneskiold-Samsøe B. Muscle strength, working capacity and effort in patients with fibromyalgia. Scand J Rehabil Med 1997;29:97–102.
14. Yunus MB, Kalyan-Raman UP, Kalyan-Raman K, Masi AT. Pathologic changes in muscle in primary fibromyalgia syndrome. Am J Med 1986;81:38–42.
15. Bennett RM. Physical fitness and muscle metabolism in the fibromyalgia syndrome: an overview. J Rheumatol 1989;16 Suppl 19:28–9.
16. Wolfe F, Smythe HA, Yunus MB, Bennett RM, Bombardier C, Goldenberg DL, et al. The American College of Rheumatology 1990 criteria for the classification of fibromyalgia: report of the multicenter criteria committee. Arthritis Rheum 1990;33:160–72.
17. Shephard RJ, Thomas S, Weller I. The Canadian home fitness test: 1991 update. Sports Med 1991;11:358–66.
18. Fillenbaum GG. Multidimensional functional assessment of

older adults: the Duke older americans resources and services procedures. Hillsdale: Lawrence Erlbaum Associates, 1988.
19. Rooks DS, Ransil BJ, Hayes WC. Self-paced exercise improves neuromotor performance in community dwelling older adults. J Aging Phys Activity 1997;5:135–49.
20. Rooks DS, Kiel DP, Parsons C, Hayes WC. Self-paced resistance training and walking exercise in community dwelling older adults: effects on neuromotor performance. J Gerontol A Biol Sci Med Sci 1997;52A:M161–8.
21. Nelson ME, Fiatarone MA, Morganti CM, Trice I, Greenberg RA, Evans WJ. Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures: a randomized controlled trial. JAMA 1994;272:1909–14.
22. Frontera WR, Meredith CN, O'Reilly KP, Knuttgen HG, Evans WJ. Strength conditioning in older men, skeletal muscle hypertrophy, and improved function. J Appl Physiol 1988;64: 1038–44.
23. Fiatarone MA, O'Neill EF, Ryan ND, Clements KM, Solares GR, Nelson ME, et al. Exercise training and nutritional supplementation for physical frailty in very elderly people. N Engl J Med 1994;330:1769–75.
24. Sparling PB, Cantwell JD, Dolan CM, Niederman RK. Strength training in a cardiac rehabilitation program: a six month follow-up. Arch Phys Med Rehabil 1990;71:148–52.
25. McCartney N, McKelvie RS, Haslam DRS, Jones NL. Usefulness of weightlifting training in improving strength and maximal power output in coronary artery disease. Am J Cardiol 1991;67:939–45.
26. Rooks DS, Silverman CB, Kantrowitz FG. Safety and reliability of the one-repetition maximum test for assessing muscle strength in women with fibromyalgia. Arthritis Rheum 1999;42 Suppl 9:5220.
27. King S, Wessel J, Bhambhani Y, Maikala R, Sholter D, Maksymowych W. Validity and reliability of the 6 minute walk in persons with fibromyalgia. J Rheumatol 1999;26:2233–7.
28. Burckhardt CS, Clark SR, Bennett RM. The fibromyalgia impact questionnaire: development and validation. J Rheumatol 1991;18:728–33.
29. Mengshoel AM, Vollestad NK, Forre O. Pain and fatigue induced by exercise in fibromyalgia patients and sedentary health subjects. Clin Exp Rheumatol 1995;13:477–82.
30. Sall J, Lehman A. A guide to statistics and data analysis using JMP and JMP IN software. Boston, MA: Duxbury Press, 1996.
31. Simms RW, Roy SH, Hrovat M, Anderson JJ, Skrinar G, LePoole SR, et al. Lack of association between fibromyalgia syndrome and abnormalities in muscle energy metabolism. Arthritis Rheum 1994;37:794–800.
32. Jubrias SA, Bennett RM, Klug GA. Increased incidence of a resonance in the phosphodiester region of ^{31}P nuclear magnetic resonance spectra in the skeletal muscle of fibromyalgia patients. Arthritis Rheum 1994;37:801–7.
33. Nørregaard J, Bülow PM, Mehlsen J, Danneskiold-Samsoe B. Biochemical changes in relation to a maximal exercise test in patients with fibromyalgia. Clin Physiol 1994;14:159–67.
34. Jacobsen S, Wildschiodtz G, Danneskiold-Samsøe B. Isokinetic and isometric muscle strength combined with transcutaneous electrical muscle stimulation in primary fibromyalgia syndrome. J Rheumatol 1991;18:1390–3.
35. Hakkinen A, Hakkinen K, Hannonen P, Alen M. Force production capacity and acute neuromuscular responses to fatiguing loading in women with fibromyalgia are not different from those of healthy women. J Rheumatol 2000;27:1277–82.
36. Bailey A, Starr L, Alderson M, Moreland J. A comparative evaluation of a fibromyalgia rehabilitation program. Arthritis Care Res 1999;12:336–40.
37. McCain GA. Role of physical fitness training in the fibrositis/fibromyalgia syndrome. Am J Med 1986;81:73–7.
38. Moldofsky H, Scarisbrick P. Induction of neuroasthenic musculoskeletal pain syndrome by selective sleep deprivation. Psychol Med 1976;38:35–44.
39. Bennett RM, Burckhardt CS, Clark SR, O'Reilly CA, Wiens AN, Campbell SM. Group treatment of fibromyalgia: a 6 month outpatient program. J Rheumatol 1996;23:521–8.
40. Burckhardt CS, Mannerkorpi K, Hedenberg L, Bjelle A. A randomized, controlled clinical trial of education and physical training for women with fibromyalgia. J Rheumatol 1994; 21:714–20.
41. Gowans SE, deHueck A, Voss S, Richardson M. A randomized, controlled trial of exercise and education for individuals with fibromyalgia. Arthritis Care Res 1999;12:120–8.
42. Martin L, Nutting A, MacIntosh BR, Edworthy SM, Butterwick D, Cook J. An exercise program in the treatment of fibromyalgia. J Rheumatol 1996;23:1050–3.
43. Mengshoel AM, Komnes HB, Forre O. The effects of 20 weeks of physical fitness training in female patients with fibromyalgia. Clin Exp Rheumatol 1992;10:345–9.
44. Nichols DS, Glenn TM. Effects of aerobic exercise on pain perception, affect, and level of disability in individuals with fibromyalgia. Phys Ther 1994;74:327–32.
45. Borg GAV. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982;14:377–81.
46. Fiatarone MA, Marks EC, Ryan ND, Meredith CN, Lipsitz LA, Evans WJ. High-intensity strength training in nonagenarians. JAMA 1990;263:3029–34.