Acute Heavy-Resistance Exercise–Induced Pain and Neuromuscular Fatigue in Elderly Women With Fibromyalgia and in Healthy Controls

Effects of Strength Training

Heli Valkeinen,1 Arja Häkkinen,2 Pekka Hannonen,2 Keijo Häkkinen,1 and Markku Alén1

Objective. To examine heavy-resistance exercise–induced acute neuromuscular fatigue, blood lactate concentration, and muscle pain in elderly women with fibromyalgia (FM) and in healthy controls before and after a period of strength training.

Methods. Thirteen elderly women with FM (mean ± SD age 60 ± 2 years) and 10 healthy women (mean ± SD age 64 ± 3 years) performed a heavy-resistance fatiguing protocol (5 sets of leg presses with 10 repetitions maximum) before and after a 21-week strength training period. Maximal isometric force and electromyography (EMG) activity of leg extensors and blood lactate concentration were measured during the loading. Pain was assessed by visual analog scale.

Results. The strength training 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.

Conclusion. The increased strength in women with FM improved high-load performance and also seemed to attenuate perceived pain. Acute exercise-induced neuromuscular changes and the time course of muscle pain in women with FM were comparable with findings in healthy controls, which suggests a typical fatiguing process and a similar trainability of the muscles in elderly women with FM.

Muscle pain is one of the main symptoms in patients with fibromyalgia (FM), but no clear muscle abnormalities have been found. Altered peripheral nociceptive mechanisms and central pain processing appear to lead to augmented pain in FM (1). Both pharmacologic and nonpharmacologic interventions are effective in the management of FM (2). Nevertheless, it is a common belief that FM patients are unable to train due to the pain induced by an inappropriate amount or intensity of exercise. Therefore, it is of major importance to test this prejudice. Further, it is of practical interest to know whether general FM pain is distinguishable from exercise-induced muscle pain (delayed-onset muscle soreness [DOMS]).

Long-term and regular strength training improves muscle strength (3–5) and voluntary neural activity (3,5) similarly in patients with FM and in healthy controls. Recent strength training (5) and aerobic performance studies (2) indicate that general FM pain may be reduced during the training.

Less is known about the acute effects of a single strenuous heavy-resistance exercise or training session on DOMS and on neuromuscular functions in patients...
with FM. Increased (6) and similar (7) exercise-induced pain has been reported in patients compared with healthy controls. Studies have also shown that middle-aged patients have normal physiologic muscle fatigue responses measured by various fatiguing protocols (7,8). No relationships between decreased muscle performance and clinical findings, such as pain severity, have been found (9).

The main principles of strength training are regularity, overload, and progression (in terms of intensity, number of repetitions, and frequency). A single training session should cause some acute fatigue, which, in turn, leads to adaptation of the neuromuscular system during regular training. Acute muscle fatigue in patients with FM has been tested using different protocols (7,8), but to date only 1 study (7) has examined acute neuromuscular fatigue and DOMS in middle-aged patients with FM, using a loading session typically applied in strength training. The purposes of the present study were 1) to examine acute fatigue of the neuromuscular system, blood lactate concentration, and DOMS in elderly women with FM and healthy women during and subsequent to a heavy-resistance fatiguing loading protocol and 2) to study whether the responses to acute fatiguing loading change after the 21-week strength training period and differ between women with FM and healthy women. Because our subjects were elderly patients with a rather long history of FM, we hypothesized that their acute responses to fatiguing loading would not be as great as those of healthy age-matched women and their acute responses to fatiguing loading would not improve comparable with those of healthy controls.

PATIENTS AND METHODS

Subjects. An informative description of the present study was sent to ~100 elderly female patients with FM at the local patient organization and our outpatient clinic. Inclusion criteria were female sex, age >55 years, diagnosis of FM according to the American College of Rheumatology criteria (10), and willingness to train. Based on the replies and the inclusion criteria, 60 patients were considered for study. Exclusion criteria were cardiovascular disease, diabetes, malfunctions of the thyroid gland, or any other disease that may interfere with musculoskeletal functions or the ability to train according to the study plan. Regular strength training during the year before the study was also an exclusion criterion. Twenty patients met exclusion criteria and 14 patients were excluded after examination by a rheumatologist (PH). Thus, 26 patients were enrolled. In the present report, the initial fatiguing loading data from elderly women with FM are presented because this is a subgroup analysis of our previous study (11).

Eleven healthy women from the town of Jyväskylä served as controls, and they fulfilled the same criteria as the patients except for a diagnosis of FM. During the experimental period, the subjects in both groups continued their aerobic physical activities, such as walking and biking 1–3 times per week, in the manner to which they were accustomed before the training period. All subjects were carefully informed about the study design and potential risks involved, and all provided written consent prior to the initiation of the study. The study was approved by the local ethics committee.

Experimental design. Women with FM and healthy women carried out strength training for 21 weeks and were tested at week 0 and at week 21. This report includes the results of the fatiguing loading protocol that was performed before and after the supervised strength training period. The detailed results of the training effects on muscle strength and muscle mass have been previously reported (11).

Fatiguing loading. The heavy-resistance fatiguing loading protocol included bilateral dynamic leg press exercise on the David 210 machine (David Fitness and Medical, Outo-kumpu, Finland). During this exercise, the subject extended her knees repeatedly from an initial position of 70° to full extension (180°) and thereafter lowered the load eccentrically back to the starting position for the next concentric repetition. The loads were individually adjusted during the course of the session due to fatigue, so that each subject would be able to perform 10 repetitions in each set for a total of 5 sets (5 × 10 repetitions maximum [RM]). If the load became too heavy, the subject was assisted slightly during the last 1–3 repetitions of the set, while she maintained her maximum performance and the required number of repetitions was reached. The recovery time between sets was 2 minutes (7). The average load per set (kilograms × 10 repetitions) was calculated for the 5 sets.

Testing of muscle force and electromyography (EMG). Before the fatiguing loading began, maximal isometric bilateral leg extension force was measured with a dynamometer. On verbal command, the subject was asked to produce maximal force (at the knee angle of 107°) as fast as possible and maintain it for 3–5 seconds. At least 3 maximal isometric trials were performed, and the best result (in newtons) was used for the analysis (11,12). Immediately after every set, 1 maximal isometric trial was performed to study changes in muscle strength due to fatigue. EMG activity of the right vastus lateralis (VL) and vastus medialis (VM) muscles was recorded during the maximal isometric leg extension, with bipolar (20 mm interelectrode distance) surface EMG electrodes (miniature skin electrodes 650437; Beckman, Chicago, IL) according to the method previously described (11,12). Results are expressed as the mean integrated EMG activity of the right VL and VM muscles.

Blood lactate concentration. Blood lactate concentration was analyzed using the fingertip blood samples taken before the loading, immediately after the third and the last sets, as well as 15 and 30 minutes after the loading.

Pain. DOMS was measured with a 100-mm visual analog scale (VAS) on the loading day and on 6 successive days after the loading. Subjects were asked to note feelings of pain, especially in the lower body muscle groups such as the lower back, buttocks, and legs. General FM pain was recorded on a VAS the day before the loading at weeks 0 and 21.
Experimental strength training program. Both groups carried out strength training under supervision twice a week for 21 weeks. All training sessions started with a warmup and ended with cool down exercises. Each training session included 2 exercises for the knee extensor muscles: the bilateral leg press exercise and the bilateral or unilateral knee extension exercise, performed on the David 200 machine (David Fitness and Medical), and 4–5 other exercises were performed for the other main muscle groups of the body to guarantee overall improvements in muscle strength. The program intensity increased progressively from 50% to 80% of 1 RM, and the loads were determined during the training sessions throughout the study according to the maximum repetition method. The subjects kept an exercise diary (3,12).

Statistical analysis. Data are expressed as the mean ± SD. Normality of the variables was analyzed by the Kolmogorov-Smirnov test, and differences between groups at baseline were analyzed by Student’s unpaired t-test. To test the significance of changes during fatiguing loading and effects of the strength training period, we evaluated all variables separately using repeated-measures analysis of variance (ANOVA). The between-subjects independent variable was group (FM patients versus healthy women), and the within-subject independent variable was time (pretraining versus posttraining and preloading versus postloading). A nonsignificant interaction would indicate that there may be no divergent changes across time between the study groups.

To compare changes in the loadings between the groups, we calculated the percentage change in each variable at week 0 and week 21 and analyzed these changes by repeated-measures ANOVA. The results for variables with several measurements (blood lactate concentration and pain) are reported using within-subject contrasts (Bonferroni adjusted). \(P\) values less than 0.05 were considered significant.

RESULTS

The mean ± SD age of the women with FM was 60 ± 2 years. Their mean ± SD height and weight were 159 ± 4 cm and 66 ± 9 kg. The healthy controls had a mean ± SD age of 64 ± 3 years, height of 160 ± 6 cm, and weight of 70 ± 6 kg. The mean ± SD time since diagnosis of FM was 8.5 ± 4 years, and the patients had presented with 17 ± 2 palpable tender points at baseline. The patients were allowed to continue taking their own medications during the entire study period: 5 subjects took painkillers, 6 took muscle relaxants, and 7 took antidepressants. One healthy subject dropped out after 7 weeks of training due to family reasons, and her results were not included in the analysis. Thus, we performed all analyses with 10 healthy controls. All patients completed the study and were able to perform the fatiguing loading before and after the training period. The percentage of completed workouts was 98.9% in the healthy controls and 95.2% in the patients.

Changes during the acute loadings. At week 0, the average load per set and the maximal isometric leg extension force were lower in women with FM than in healthy women (\(P = 0.040\) and \(P = 0.022\), respectively). During the loading, isometric force decreased to the same extent between the groups (interaction \(P = 0.394\)). In women with FM and in healthy women, the decreases were 25% and 23%, respectively (\(P < 0.001\)) (Figure 1).

At week 21, the average load per set did not differ significantly between the groups. However, isometric force remained lower in women with FM than in healthy controls (\(P = 0.004\)). During the loading, the decrease in isometric force differed between the groups (interaction \(P = 0.006\)); the decreases were 26% and 29% in women with FM and healthy women, respectively (\(P < 0.001\)). The percentage change of EMG activity (preloading versus postloading) at weeks 0 and 21 did not differ significantly between or within the groups (Figure 1).

At weeks 0 and 21, the percentage increases in blood lactate concentration did not differ significantly between the groups, but the increases were significant within the groups (\(P < 0.001\)) (Figure 2). The highest level of blood lactate concentration in both groups was reached at the end of the loadings (postloading value).
EFFECTS OF STRENGTH TRAINING IN FM

The 2 groups.

FIGURE 2. Blood lactate concentration levels during heavy resistance loading. Concentrations of blood lactate are shown for women with fibromyalgia (FMW) and healthy female controls (HW) at week 0 and week 21 of the strength training period. Values are the mean and SD.

At week 0, the blood lactate concentration returned to the preloading level during the 30-minute recovery period, while at week 21 it remained elevated in both groups (P < 0.01).

Women with FM reported more pain (the average pain value of all measured days) than healthy women at weeks 0 and 21 (P < 0.05) (Figure 3). At week 0, DOMS reaction differed between the groups (interaction P = 0.015), but no differences were observed at week 21 (interaction P = 0.558). Both groups reported the highest DOMS on days 1 and 2 after the loading (P < 0.05).

Comparing percentage changes of the acute loadings before (week 0) and after (week 21) the strength training period between the groups, no significant differences were observed in average load per set, isometric force, EMG activity, blood lactate concentration, or pain. Within the groups, a mean ± SD increase of 41 ± 16% in the average load per set in women with FM (from 805 kg at week 0 to 1,128 kg at week 21; P < 0.001) and of 26 ± 8% in healthy women (from 943 kg to 1,189 kg; P < 0.001) was observed. Both groups had lower blood lactate increases at week 0 than at week 21 (264% versus 457%; P = 0.029 and 135% versus 275%; P < 0.001 in women with FM and healthy women, respectively), and both groups also reported less DOMS during days 1 and 2 at week 21 than at week 0 (P < 0.05).

FIGURE 3. Pain in women with fibromyalgia (FMW) and healthy female controls (HW) before, on the day of, and during the 6 days after heavy resistance loading, measured by 10-mm visual analog scale. Data shown are for week 0 and week 21 of the strength training period. Values are the mean and SD. * = P < 0.05 within each group; # = P = 0.015 between the 2 groups; ## = no significant difference between the 2 groups.

Changes during the strength training period. During the 21-week strength training period no changes in isometric force were observed between the groups (interaction P = 0.089). Isometric force increased by a mean ± SD of 35 ± 32% (P < 0.001) in women with FM (baseline value 1,147 ± 403N) and by 37 ± 21% (P < 0.001) in healthy women (baseline 1,516 ± 281N). Also, the maximum EMG increased from 114 ± 47 μV·second by 46 ± 35% (P < 0.001) in women with FM and from 110 ± 37 μV·second by 19 ± 29% (P < 0.001) in healthy women, but no differences were seen between the groups (interaction P = 0.089).

At baseline, the general pain level (measured by VAS 1 day before the loading) was greater in women with FM than in healthy women (P = 0.003). During the training period, significant changes were observed in the general pain level between the groups (interaction P = 0.021) due to a positive training effect seen in women with FM (Figure 3).

DISCUSSION

Our results showed that heavy-resistance fatiguing loading caused remarkable acute decreases in maximal force and increases in blood lactate concentration at weeks 0 and 21 in women with FM and healthy women. The average load per set, maximal peak force, and maximal EMG activity of the trained muscles increased during the 21-week strength training period in both groups. More importantly, the training period seemed to attenuate DOMS and the general pain level in the patients.

Some studies have suggested that the initial muscle strength level of FM patients would be lower than that of healthy controls due to pain, reduced physical activity, or both (13). However, in the present study the patients improved their muscle strength to the same extent as the healthy controls during the training period despite their relatively long disease history. This indicates that the trainability of the muscles of elderly women with FM remains normal (5,11).

The loading sessions caused acute muscle fatigue.
associated with a notable decrease in muscle strength. Muscle strength decreased less in elderly patients than was found earlier in middle-aged patients with FM (7) and in healthy elderly compared with healthy younger subjects (14). However, the EMG activity of the loaded muscles did not decrease significantly with the loading protocol used. It is possible that the elderly subjects may not be able to fully activate their muscles during the initial sets of maximal loading (7), as also indicated by the slightly increased EMGs during the first 2 sets (Figure 1).

Our results are consistent with findings of earlier studies that measured acute muscle fatigue with various dynamic or isometric muscle fatiguing protocols (7,8). Further, we showed that the patients’ blood lactate concentration responses were comparable with those of healthy controls. An interesting finding was that both groups had clearly higher blood lactate peak concentrations at week 21 than at week 0. This also indicates that the patients’ anaerobic energy production and lactate tolerance improved during the training.

Consistent with previous studies (6,7), our subjects reported the highest postexercise DOMS on the first and second days. Moreover, DOMS was less prominent at week 21 than at week 0, which showed that the subjects adjusted to high-resistance loading due to regular training.

We would also like to emphasize that the patients’ general FM pain level was lower at week 21 than at baseline. Thus, regular strength training may attenuate FM pain. A single bout of resistance exercise has been shown to modify the sensation of experimentally induced pain in healthy adults, but the exact mechanisms of this exercise-induced analgesia are not yet clear. It has been suggested that activation of the endogenous opioid system during exercise may alleviate pain (15). Also, various stimuli, due to training, that originate from mechanoreceptors of joints and muscles might activate descending pain inhibitory pathways and alleviate pain, i.e., the sensory cortex recognizes the peripheral stimuli as less painful and additional exercise may distract attention from pain (16). Further, regular strength training causes numerous changes in muscle structure, function, and metabolism, and it is also possible that these adaptations may impose modulating effects on local nociceptors.

Alleviation of pain may also be linked to some psychological factors. The perceived pain before physical performance may serve as an “occasion setter” in patients with FM: when the perceived pain level is high, physical performance is avoided, but under low pain conditions the patient feels it is safer to be physically active (17). Thus, fear of pain may reduce physical activity and may also lead to reduced muscle performance (9). These psychological factors are another reason why exercise should be included in the treatment programs of FM patients.

The small number of subjects, however, limits the generalization of the present results. The decreased general FM pain should be interpreted with caution because it is unclear how well patients with FM can differentiate muscle soreness from general FM pain. It will be of great interest to follow up the patients for a longer period to see whether the effects of training are sustained.

In conclusion, the improved ability to resist acute fatigue and improved neuromuscular functions indicate that elderly patients with FM may achieve all the same health-related benefits of strength training as healthy individuals. These improvements increase the patients’ reserve of functional performance in everyday life. More importantly, decreased perceived pain improves patients’ self-efficacy.

REFERENCES