The Effects of 12 Weeks of Resistance Exercise Training on Disease Severity and Autonomic Modulation at Rest and After Acute Leg Resistance Exercise in Women with Fibromyalgia

J. Derek Kingsley, PhD, Victor McMillan, MD, Arturo Figueroa, MD, PhD


Objective: To determine the effects of 12 weeks of resistance exercise training (RET) on disease severity and autonomic modulation at rest and after acute leg resistance exercise in women with fibromyalgia (FM) and healthy controls (HCS).

Design: Before-after trial.

Setting: Testing and training occurred in a university setting.

Participants: Women with FM (n=9; mean age ± SD, 42±5y) and HCs (n=15; mean age, 45±5y).

Intervention: Both groups underwent testing before and after 12 weeks of whole-body RET consisting of 3 sets of 8 to 12 repetitions on 5 different exercises.

Main Outcome Measures: Disease severity was assessed using the number of active tender points, myalgic score, and the Fibromyalgia Impact Questionnaire (FIQ). Heart rate and autonomic modulation using power spectral analysis of heart rate variability (HRV) were measured at rest and 20 minutes after 5 sets of leg-press exercise.

Results: There was no group-by-time interaction for any variable. Women with FM and HCs had similar increases in maximal strength (P<.05) after RET. Number of active tender points, myalgic score, and FIQ score were decreased (P<.05) after RET 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 (P<.05) 20 minutes after acute leg resistance exercise. There were no significant effects of RET on HRV at rest or postexercise.

Conclusions: These findings indicate that cardiovagal modulation of heart rate recovery early after leg resistance exercise in women with FM and HCs. It is concluded that RET reduces the severity of FM, but it has no impact on autonomic modulation of heart rate.

Key Words: Fibromyalgia; Rehabilitation; Vagus nerve.

© 2010 by the American Congress of Rehabilitation Medicine

FIBROMYALGIA IS AN idiopathic disease characterized by widespread diffuse full-body pain, decreased muscular strength and endurance, orthostatic intolerance, decreased cold tolerance, and fatigue. Although the cause of FM is unknown, data suggest that autonomic dysfunction may explain some of the symptoms. Studies that have evaluated autonomic modulation in women with FM by using HRV have reported decreased parasympathetic (vagal) tone at rest and an inability to increase sympathetic activity during a physiological stressor, such as standing or cold.

Reports investigating autonomic recovery from endurance exercise are more widespread than those using an acute bout of resistance exercise. Heffernan et al and Rezk et al both reported decreases in vagal activity after resistance exercise in young healthy men and women. Conversely, we have reported that acute resistance exercise increased postexercise vagal modulation in women with FM compared with HCs. However, 1 limitation of that study was that women with FM were closer to stage 1 obesity, whereas HCs were slightly overweight. To better evaluate the effect of exercise in women with FM, group differences in BMI should be minimized.

Studies using RET in women with FM have shown increases in maximal strength, number of active tender points, myalgic score, and FM severity, such as number of active tender points, myalgic score, and FM impact. Furthermore, although some studies reported no change in HRV after RET in young healthy men and women, Figueroa et al showed an increase in overall HRV and parasympathetic tone after 16 weeks of RET in women with FM who had autonomic dysfunction before the intervention. Therefore, the purpose of the present study was to evaluate the effects of an acute bout of resistance exercise on autonomic modulation at rest and postexercise and disease...
severity before and after 12 weeks of RET in women with FM compared with HCs. We hypothesized that RET would both cause greater improvements in autonomic modulation in women with FM compared with HCs and decrease disease severity.

METHODS

Participants
Participants were recruited from the local community through newspaper advertisements. Of the initial 332 women interviewed, only 29 premenopausal women aged 35 to 50 years met the necessary criteria to participate in the study (fig 1). Participants were categorized as either having a clinical diagnosis of FM (n=9) or as an HC (n=20). Inclusion criteria included a diagnosis of FM by a board-certified rheumatologist,1 premenopausal, and no history of chronic diseases. Women were excluded if they had exercised within the past year, had smoked within the past 6 months, had a history of chronic diseases, had BMI less than 25kg/m² or more than 35kg/m², were using any form of estrogen/progesterone, or were using any medications that altered cardiovascular function. Medications being used by the women with FM in the beginning and throughout the study were sleep aids (n=3) or painkillers (n=1). None of the HCs were using any medication. All participants gave written consent, as approved by the Institutional Review Board of Florida State University.

Study Design
Participants were tested at baseline (before) and after a 12-week RET period (after) for all variables. There were 6 visits in each period. Testing at each period occurred over 2 weeks. The initial visit consisted of orientation, which included signing the informed consent, and questionnaires. Number of active tender points, myalgic score, and FIQ score were collected on the second and sixth visits to the Rheumatology Clinic. Participants then underwent measurements of muscle strength and anthropometrics on both the third and fourth visits. The fifth visit consisted of measurements of autonomic modulation at rest and postexercise. All measurements at these times were conducted at the same time of day to reduce possible diurnal physiologic variations. All participants refrained from using any medication 24 hours before any of the testing procedures. Participants returned to the laboratory for testing 48 hours after the last exercise session. Participants were asked to maintain their present habits during the course of the study.

Tender Points
The diagnosis of FM was made in all women by a board-certified rheumatologist (V.M.) in a blinded manner according to the guidelines of the American College of Rheumatology1 on 2 separate occasions before participating in the study and after RET. Diagnosis was defined as pain in 3 of 4 quadrants of the body, pain for 3 months, and pain upon pressure on 11 of 18 specific tender points.1 In the present study, all of the women were examined for both the number of active tender points and total myalgic score. The total myalgic score was assessed by assigning each active tender point a sensitivity score of 0 (no pain) to 3 (withdrawal of the subject from the examiner) for each of the 18 tender points, which were totaled for a possible total myalgic score of 54 units.2 The rheumatologist was blinded to the group assignment of participants but not to the intervention. For the 9 women with FM, test-retest correlations (r) for the number of active tender points and myalgic score before RET were .99 and .98, respectively.
Fibromyalgia Impact Questionnaire

The FIQ was used to determine the impact of FM on a week-to-week basis. The FIQ consists of 20 questions that assess such items as the ability to perform activities of daily living, well-being, and symptoms of FM. The higher the FIQ score, the greater the impact of the disease. The average woman with FM scores 50 units, whereas a more severely impacted woman with FM has scores of 70 units and higher. The FIQ has been shown to be both a reliable and valid questionnaire for the impact of FM.

Anthropometry

Body weight was measured on a Seca® balance beam scale to the nearest 0.1 lb, which subsequently was converted to kilograms for further analysis. Height was measured using a Medicare® stadiometer to the nearest centimeter. BMI was calculated as weight (kg)/height (m²).

Maximal Strength

Maximal strength tests were performed on MedX® machines for the chest press, leg press, seated row, leg extension, and leg curl. After a brief warm-up with a light resistance load, participants were progressed until a resistance load was ascertained that could be moved 1 time through a complete range of motion. All measurements were recorded within 3 to 5 attempts. After a minimum of 72 hours of rest, participants returned for verification of the 1RM. The highest resistance load attained was defined as the 1RM.

Acute Effects of Resistance Exercise on Autonomic Modulation

Participants arrived at the laboratory after a 12-hour fast, with no caffeine ingestion for at least 12 hours, and having abstained from strenuous exercise for 24 hours. After a 20-minute rest period, autonomic modulation was measured during 5 minutes (fig 2) using an ECG. Immediately after exercise cessation, participants returned to the seated position. A postexercise ECG was obtained between minutes 20 and 25. A metronome was set to regulate the participant’s breathing at 12 breaths/min while obtaining the ECG.

HRV was evaluated in the manner described by the European Task Force on HRV. Electrocardiographic signals were collected at a rate of 1000Hz using a modified CMS configuration interfaced with a Biopac® data acquisition system. WinCPRS® software was used to import the ECG and extract the beat-by-beat R-R interval after visual inspection of noise, ectopics, and artifacts. Because small sections of beats were collected, for a duration of 2 to 5 minutes, Fast Fourier transformation was used to generate spectral power and time domains. Total power of HRV is used as an index of total autonomic nervous system activity. Studies suggest that LF (.04–.15Hz) power of HRV is mediated by both sympathetic and parasympathetic modulations. HF (.15–.4Hz) power of HRV is indicative of parasympathetic modulation. The power for each individual frequency is evaluated by examination of the total area under the curve for that component and may be expressed in absolute (milliseconds squared) or normalized units.

The acute resistance exercise was administered, consisting of 5 sets of 10-RM on the leg press (MedX). The 10-RM was derived from the previously determined 1RM using the equation from Brzycki. A 2-minute rest period was given between each set. When participants were fatigued, assistance was given on the last 1 to 3 repetitions so that the required 10 repetitions could be completed with proper form. The acute resistance exercise bout lasted 15 minutes.

Resistance Exercise Training

Individual supervised RET was performed twice a week for 12 weeks, with each session separated by at least 48 hours. The training protocol was identical for both groups and included 3 sets of chest press, seated row, leg extension, and leg curl exercises on MedX machines. Initial training intensity was set at 50% to 60% and progressed to 75% to 85% of the 1RM for the upper and lower body after 8 weeks, respectively. Rest periods (for 90s) were provided between sets and exercises. When the participant was able to perform 3 sets of 12 repetitions on 2 consecutive training days, resistance was increased by 2% to 10%, as recommended by the American College of Sports Medicine. Training sessions lasted approximately 30 minutes.

Statistics

Baseline characteristics of the groups were analyzed using Student t test. Because a Kolmogorov-Smirnov normality test determined that absolute values for total power, LF, and HF were not normally distributed, they subsequently were transformed to their Ln. A repeated-measures ANOVA was used to test the effects of group (FM and HCs) and time (before and after RET) on the number of active tender points, myalgic score, FIQ score, and maximal strength. Another ANOVA was used to determine the effects of group across time and condition (rest vs postexercise) on heart rate, LnLF, LnHF, and LnLF/LnHF ratio. If interactions were significant using ANOVA, t tests were used for post hoc comparisons. Significance was set a priori at P less than .05. Values are presented as mean ± SD and 95% CI. All statistical analyses were performed using SPSS.

RESULTS

Five of the 20 original HCs withdrew from the study before RET because of family-related issues (n=3) or scheduling conflicts (n=2). No women with FM withdrew from the study. Adherence to the RET was similar between groups (FM and HCs, 88% vs 91%; P>.05). There were no group differences in age, height, weight, and BMI (table 1) at any time between the women with FM and HCs. Participant characteristics did not change over time.
Maximal Strength and FM Severity

The number of active tender points, myalgic score, and FIQ score were significantly (P<.05) higher in women with FM than in the HCs at all times. In the women with FM, RET without an aerobic exercise component reduced the number of active tender points (P<.05), myalgic score (P<.05), and FIQ score (P<.05) (table 2). There was no difference (P>.05) in maximal strength before or after RET between women with FM and HCs (table 3). Maximal strength increased significantly (P<.05) in response to RET in both groups for the chest press (FM and HCs, 32% [95% CI, 21.67–42.41] and 35% [95% CI, 27.60–42.41]), leg press (36.5% [95% CI, 20.67–52.40] and 27.7% [95% CI, 18.48–37.01]), seated row (23% [95% CI, 15.54–30.41] and 19.7% [95% CI, 15.73–23.86]), leg extension (39.1% [95% CI, 30.82–48.18] and 39.5% [95% CI, 31.90–46.29]), and leg curl (29.2% [95% CI, 19.83–38.65] and 39.7% [95% CI, 32.61–46.79]).

Autonomic Modulation

There was no group-by-time-by-condition interaction for heart rate and HRV before or after RET (table 4). There was a significant (P<.05) effect of the acute leg resistance exercise on LnLF (FM and HCs: before, .68 [95% CI, .06 to 1.31], .37 [95% CI, −.40 to 1.13] and after, .25 [95% CI, .73 to −.24], .27 [95% CI, −.37 to .91]) and LnHF/LnLF ratio (FM and HCs: before, .10 [95% CI, −.01 to .21], .01 [95% CI, −.05 to 0.07] and after, .04 [95% CI, −.07 to .15], .06 [95% CI, −.15 to .16]) both before and after RET, such that they were increased above at rest. LnHF was unaffected by the acute leg resistance exercise.

### Table 1: Participant Characteristics Before and After RET for Women With FM and HCs

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before (mean ± SD)</th>
<th>After (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease duration (y)</td>
<td>FM: 2.0 ± 0.4</td>
<td>HCs: 2.0 ± 0.4</td>
</tr>
<tr>
<td>Age (y)</td>
<td>FM: 42 ± 5</td>
<td>HCs: 42 ± 5</td>
</tr>
<tr>
<td>Height (m)</td>
<td>FM: 1.64 ± 0.6</td>
<td>HCs: 1.67 ± 0.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>FM: 80.8 ± 9.8</td>
<td>HCs: 77.2 ± 9.7</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>FM: 30.4 ± 3.4</td>
<td>HCs: 27.4 ± 2.3</td>
</tr>
</tbody>
</table>

NOTE. Women with FM (n=9) and HCs (n=15). Values expressed as mean ± SD. Abbreviation: NA, not applicable.

### Table 2: FM Severity Before and After RET in Women With FM and HCs

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before (mean ± SD)</th>
<th>After (mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tender points (units)</td>
<td>FM: 13 ± 3</td>
<td>HCs: 0</td>
</tr>
<tr>
<td>Myalgic score (units)</td>
<td>FM: 13 ± 3</td>
<td>HCs: 0</td>
</tr>
<tr>
<td>FIQ (units)</td>
<td>FM: 52 ± 17.5</td>
<td>HCs: 7.7 ± 7.5</td>
</tr>
</tbody>
</table>

NOTE. Women with FM (n=9) and HCs (n=15). Values expressed as mean ± SD.

DISCUSSION

The main findings of the present study were that autonomic modulation was similar at rest and after acute leg resistance exercise between women with FM and HCs. Furthermore, there were no differences in autonomic modulation between women with FM and HCs before or after RET. Additionally, 12 weeks of whole-body RET decreased disease severity in women with FM.

Women with FM had levels of maximal strength similar to HCs before beginning the intervention and after RET (P>.05). This result contradicts previous studies that have shown lower muscular strength in women with FM compared with HCs before RET. Regardless, in the present study, RET increased maximal strength (P<.05) in both groups of women, which agreed with previous data indicating that women with FM had the same ability to develop muscular strength as HCs.

Before RET, the number of active tender points and the myalgic score, although sufficient for the diagnosis of FM, were lower than those reported in other studies. In addition, FIQ scores were lower in the present study compared with previous reports in women with FM. In the present study, there were significant decreases in the total number of active tender points, myalgic score, and FIQ score in women with FM after RET. After RET, the number of active tender points was on average less than the number necessary for diagnosis (<11). Only 1 of the 9 women with FM would meet diagnostic criteria for FM based on the number of active tender points after RET. A recent study by Panton et al. showed decreases in number of active tender points, myalgic score, and FIQ score after a 16-week RET program. Taken together, these data show that RET is a useful modality for the treatment of FM.

Consistent with our previous study, women with FM were not different from HCs for heart rate at rest and parameters of...
Recent reports have shown that heart rate and LF/HF ratios in women with FM compared with age-matched controls at rest. Both Cohen et al. and Furlan et al. collected data in the supine position. Similar to the recent report, data collection in the seated position likely explains the discrepancy in HRV at rest between our data and those from previous studies. Moving from a supine position to a seated position increases heart rate through vagal withdrawal. Although vagal withdrawal may be slight, it may have been a sufficient stimulus to eradicate any significant difference compared with previous studies.

Although there are multiple reports investigating acute aerobic exercise on HRV, only a few studies have investigated the acute effects of resistance exercise. Our data have shown that acute resistance leg exercise did not alter heart rate, but affected autonomic modulation similarly in women with or without FM. We found that an acute bout of leg resistance exercise increased sympathetic activity (LnLF and LnLF/LnHF ratio) in women with FM compared with HCs without altering heart rate. Although women with FM were closer to stage 1 obesity and HCs were slightly overweight, the groups were closely matched for BMI in the present study. A previous study observed delayed heart rate recovery 20 minutes after acute endurance exercise in obese diabetic, but not in nondiabetic, women with stage 1 obesity and HCs were slightly overweight, the groups were closely matched for BMI in the present study. A previous study observed delayed heart rate recovery 20 minutes after acute endurance exercise in obese diabetic, but not in nondiabetic, women with stage 1 obesity and HCs were slightly overweight, the groups were closely matched for BMI in the present study.

**Table 4: Heart Rate and Heart Rate Variability at Rest and Postexercise Before and After RET in Women With FM and HCs**

<table>
<thead>
<tr>
<th>Variable</th>
<th>At Rest</th>
<th>Postexercise</th>
<th>At Rest</th>
<th>Postexercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate (beats/min)</td>
<td>FM 81±8</td>
<td>80±9</td>
<td>FM 78±9</td>
<td>79±14</td>
</tr>
<tr>
<td></td>
<td>HCs 75±15</td>
<td>78±19</td>
<td>HCs 75±12</td>
<td>76±11</td>
</tr>
<tr>
<td>Ln total power (ms²)</td>
<td>FM 6.2±0.6</td>
<td>6.6±0.8</td>
<td>FM 6.6±1.2</td>
<td>6.8±0.9</td>
</tr>
<tr>
<td></td>
<td>HCs 6.8±0.7</td>
<td>7.0±0.9</td>
<td>HCs 6.8±0.9</td>
<td>7.0±0.7</td>
</tr>
<tr>
<td>LnLF (ms²)</td>
<td>FM 4.3±0.9</td>
<td>5.0±1.1*</td>
<td>FM 4.9±1.0</td>
<td>5.2±1.0*</td>
</tr>
<tr>
<td></td>
<td>HCs 5.2±0.4</td>
<td>5.5±1.5*</td>
<td>HCs 5.2±1.1</td>
<td>5.5±0.7*</td>
</tr>
<tr>
<td>LnHF (ms²)</td>
<td>FM 4.9±0.6</td>
<td>5.1±1.1</td>
<td>FM 5.3±1.0</td>
<td>5.3±0.9</td>
</tr>
<tr>
<td></td>
<td>HCs 5.7±1.0</td>
<td>5.9±1.7</td>
<td>HCs 5.7±0.8</td>
<td>5.6±1.0</td>
</tr>
<tr>
<td>LnLF/LnHF ratio</td>
<td>FM 0.93±0.15</td>
<td>0.99±0.15*</td>
<td>FM 0.92±0.19</td>
<td>0.98±0.20*</td>
</tr>
<tr>
<td></td>
<td>HCs 0.89±0.17</td>
<td>0.93±0.16*</td>
<td>HCs 0.94±0.15</td>
<td>0.98±0.20*</td>
</tr>
</tbody>
</table>

NOTE: Women with FM (n=9) and HCs (n=15). Values expressed as mean ± SD.
*P<.05, significantly different from at rest.

HRV before RET. Previous studies have shown higher heart rates and LF/HF ratios in women with FM compared with age-matched controls at rest. Both Cohen et al. and Furlan et al. collected data in the supine position. Similar to our recent report, data collection in the seated position likely explains the discrepancy in HRV at rest between our data and those from previous studies. Moving from a supine position to a seated position increases heart rate through vagal withdrawal. Although vagal withdrawal may be slight, it may have been a sufficient stimulus to eradicate any significant difference compared with previous studies.

Studies investigating the effects of RET on heart rate at rest and overall HRV are limited. In the present study, there was no alteration of heart rate and measures of HRV after RET compared with before RET. Cooke et al. noted lower blood pressure responses after acute leg resistance exercise at 80% of 1RM in middle-aged than in young men. Additionally, the rapid recovery of systolic blood pressure observed 30 minutes after resistance exercise was associated with a complete return of cardiovascular activity and heart rate. Therefore, the fast return of postexercise parasympathetic modulation of heart rate would indicate that leg resistance exercise may not increase the risk for cardiac events in premenopausal women. This finding supports the use of RET in rehabilitation of women with FM.
of HRV, training significantly improved postexercise parasympathetic modulation of heart rate in middle-aged obese women with and without type 2 diabetes. Our results differ from those of Heffernan et al., who noted decreased vagal modulation of heart rate after acute resistance exercise in moderately active men. Our findings are consistent with a recent report by Figueroa et al., who showed that postexercise cardiac autonomic regulation is not affected in resistance-trained individuals.

**Study Limitations**

It is important to note that the present study had a small sample size, which may reduce the ability to interpret results. Recent data suggest that HRV collected in a small sample size may not be sensitive enough to detect physiologic alterations caused by large interindividual variability. However, despite the small sample, the 2 groups were closely matched. In addition, women with FM were not using drugs that would influence heart rate or HRV. In the women with FM in the present study, FM may not have had as much impact as in previous studies. Although FIQ scores in the present study suggested a moderate impact on participants, we controlled for many co-morbid conditions. In addition, there was no control of menstrual cycle in the present study. All participants were premenopausal and none was using exogenous estrogen. Leicht et al. showed that HRV was not affected by different stages of the menstrual cycle.

**CONCLUSIONS**

Results of this study have shown that heart rate and cardiac parasympathetic activity recovery is complete 20 minutes after a single bout of leg resistance exercise in middle-aged premenopausal women with and without FM. These results suggest that acute leg resistance exercise may not negatively affect cardiac electrical activity. Additionally, 12 weeks of whole-body RET significantly decreased disease severity in women with FM. Furthermore, alterations in heart rate at rest and postexercise and HRV are not altered by RET in premenopausal women.

**References**

7. Qiao ZG, Vaery H, Morkrid L. Electrodermal and microcirculatory activity in patients with fibromyalgia during baseline, acous-


Suppliers
a. Seca, 1352 Charwood Rd, Ste E, Hanover, MD 21076.
b. Fred Medart Manufacturing Co, Potomac St, St Louis, MO 63119.
e. Absolute Aliens, Korjasmäenkatu 16, Turku, Finland, FIN-20369.
f. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.