Resistance Training Affects Iron Status in Older Men and Women

Laura E. Murray-Kolb, John L. Beard, Lyndon J. Joseph, Stephanie L. Davey, William J. Evans, and Wayne W. Campbell

Objective: To examine the effects of resistance training on hematological and selected indices of iron status in 17 women aged 54–71 years and 18 men aged 56–69 years. Design: Tests and evaluations were done before and after all subjects participated in a resistance training program twice weekly for 12 weeks. Results: The resistance training was effective as evidenced by increases in skeletal muscle strength of 20 ± 9% and 23 ± 13% for the men and women, respectively. Hematological parameters and serum iron concentrations were within normal clinical ranges and were unchanged by resistance training for both the men and the women. Total iron binding capacity (TIBC) and transferrin saturation were also unaffected by resistance training in the women but were significantly affected in the men. The men showed a decreased TIBC ($p < .0001$) and an increased transferrin saturation ($p = .050$). Serum ferritin concentrations decreased significantly in the women ($p = .041$) but were unchanged in the men. Transferrin receptor concentrations were unaffected by resistance training in the women but increased significantly in the men ($p = .030$). Conclusions: With resistance training, iron status of older men and women changes in a sex specific way.

Key Words: aging, ferritin, transferrin receptor, strength training, exercise, body composition, chromium picolinate

Introduction

Resistance training has been established as a safe and effective way for older individuals to significantly increase muscle strength and mass (12, 15, 21). It is also associated with an increase in lean body mass as well as a decrease in fat mass in older people (9, 28). Frail elderly people can further benefit from resistance training

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by improvements in physical functional capacity, which leads to the possibility of a more healthy and independent lifestyle (13).

While resistance training by older people has many physiological, metabolic, and functional benefits, the possible effects on the nutritional status of older individuals have yet to be elucidated. Of particular interest are the possible effects on iron status. Iron plays a vital role in the transport of oxygen and carbon dioxide by the blood and in cellular respiration. It is also needed for various tissue enzymes that are critical for energy production as well as enzymes necessary for immune system functioning. Therefore, iron deficiency causes a decreased physical work capacity and excess lactate formation (24).

Studies (11, 22, 33) of aerobic exercise on iron status in both young and elderly men and women have shown a decrease in serum iron and transferrin saturation and an increase in total iron binding capacity (TIBC). Some of the studies indicated a decrease in serum ferritin concentration, while others showed an increase in erythrocyte protoporphyrin. The specific parameters affected seem to be dependent on the intensity as well as the frequency of exercise. Because aerobic exercises are implicated in deleterious changes in iron status, it is logical to question the effects of anaerobic-type exercises on iron status. We are particularly interested in resistance training.

Reports describing the effects of resistance training on iron status are sparse and limited. A few studies (19, 27, 31) in young men suggest that resistance training impacts negatively on iron status. One study (20) examined the combined effects of resistance training and aerobic exercise on the iron status of young men as well as women. This study reported a decrease in the iron stores of both the young women and men.

Recently, we reported the effects of resistance training on the iron status of older men (8). We found that with 12 weeks of resistance training, TIBC decreased significantly while transferrin saturation increased significantly. Mean serum iron concentration as well as mean serum ferritin concentration did not change significantly with resistance training.

To date, studies showing the effects of resistance training on the iron status of older women as well as comparisons of gender effects are nonexistent. Therefore, the purpose of the present study was to assess the effects of resistance training on selected indices of iron status and hematological parameters in older women and to compare the results to our findings in older men. Portions of data on the men in this study were reported previously (8) and are reported again only for descriptive and comparative purposes. Additional indices are now presented (C-reactive protein, transferrin receptor, and dietary iron intake). An identical protocol was used to study the men and women.

**Methods**

**Experimental Design**

All baseline testing and evaluations were done during study week 1, before any of the subjects started either the nutritional supplementation or resistance training interventions. Testing and evaluations were repeated during study weeks 7 and 13. Data on men as well as women spanned all seasons, and the resistance training program was exactly the same for the men and women.
Subjects

Subjects were 17 moderately overweight postmenopausal women, age range 54–71 years and 18 moderately overweight men, age range 56–69 years. Each individual was eligible for this 13-week study after completing a screening evaluation that included a medical history, a physician administered physical examination, a resting and resistance exercise electrocardiogram, a 3-hour, 75-g dextrose oral glucose tolerance test, and routine blood and urine chemistries. Individuals with any of the following conditions were excluded from the study: uncontrolled hypertension, diabetes, or abnormal cardiac, liver, or kidney function. Women on estrogen replacement therapy were also excluded from the study. Written informed consent was obtained from each person after receiving written and verbal explanations of the study. The study protocol and informed consent agreement were reviewed and approved by the Institutional Review Board, The Pennsylvania State University, University Park, PA. The protocol was also reviewed and approved by the General Clinical Research Center (GCRC) Advisory Committee, The Pennsylvania State University, University Park, PA.

Body Weight and Height Measurements

Fasting body weight was measured each weekday during study weeks 1, 7, and 13, and twice weekly during the other study weeks. Weights were taken to the nearest 0.1 kg with the subject wearing underwear, socks, T-shirt, and gym shorts. Nude body weight was calculated as total body weight minus socks, T-shirt, and gym shorts weight. Body height without shoes was measured to the nearest 0.1 cm with a wall-mounted stadiometer one morning during week 1.

Nutritional Intake and Supplementation

Three-day dietary food records were obtained from each subject during study weeks 2 and 12. The food records were complete for all individuals with the exception of 3 men. Therefore, data from the food records of those 3 men were excluded from analysis. All of the data were processed using Nutritionist IV Software (Version 4.0; N-Squared Computing, First Data Bank, San Bruno, CA). After total iron intake was assessed for each individual, values were adjusted for enhancing as well as inhibitory factors to determine availability of the dietary iron. This was accomplished by using the method proposed by Tseng et al. (32).

The data presented in this report were obtained retrospectively. This study was originally designed to study the effects of high dose chromium picolinate supplementation along with resistance training on body composition and glucose metabolism in older individuals. Therefore 9 of the women and 9 of the men were asked to consume 2 capsules of chromium picolinate daily (462 ± 11 μg Cr/capsule), while 8 of the women and 9 of the men were assigned to a placebo group. No other supplements were consumed by any of the subjects. A detailed description was reported previously (8). Statistical evaluation of the data showed that chromium picolinate had no impact on any of the measured parameters. Therefore, data from the chromium supplemented group and the placebo group were collapsed for analysis and presentation purposes.
**Resistance Training Protocol**

During study weeks 2–13, all subjects participated in a high-intensity progressive resistance training program. Twice weekly, each individual performed three sets of eight repetitions at 80% of their predetermined (baseline) one repetition maximum (1RM) for unilateral knee extension, unilateral knee flexion (the women performed bilateral knee flexion), double leg press, seated chest press, and seated arm pull exercises. For the first two sets, eight repetitions were performed, and for the third set, repetitions were continued until voluntary muscular fatigue or until 12 repetitions were performed. If 12 repetitions were completed, the resistance for that exercise was increased 5% for the next exercise session. 1RM testing was repeated at study weeks 7 and 13. All exercise sessions and 1RM testing were done using Keiser pneumatic resistance equipment (Keiser Sports Health Equipment, Fresno, CA). The strength data are reported as the sum of the individual 1RM values for the right knee extension, left knee extension, chest press, arm pull, and double leg press exercises. The resistance training sessions were preceded and followed by 10 min of easy cycling (heart rate < 100 beats/min) and 10 min of stretching. Compliance for the resistance training sessions was 100% for the women and men, except for one man who completed 22 out of 23 sessions.

**Blood Sampling and Analyses**

At study weeks 1, 7, and 13, fasting blood was obtained from a catheterized antecubital vein and divided into plasma, serum, and whole blood samples. Hematocrit, hemoglobin, red blood cell (erythrocyte) count, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, red blood cell (erythrocyte) distribution width, platelet count, mean platelet volume, and white blood cell (leukocyte) count, were measured with a Coulter Microdiff 16 instrument (Coulter Electronics, Hialeah, FL) using the standard methods of the instrument.

Serum iron concentrations and total iron binding capacity (TIBC) were measured by coulometry (Ferrochem II, ESA, Inc., Bedford, MA) as previously described (6), and then transferrin saturation was calculated. The between assay coefficient of variation was 3.3% for serum iron and 1.3% for TIBC. Serum ferritin concentrations were measured by commercial radioimmunoassay (Coat-a-count Ferritin IRMA, Diagnostic Products Corporation, Los Angeles, CA). Transferrin receptor concentrations were measured by ELISA (Ramco, Houston, TX). The transferrin receptor-ferritin ratio was then calculated. All analyses included an internal sample for quality control purposes. The between assay coefficient of variation was <4% for the ferritin analyses and <7% for the transferrin receptor analyses. Because the measurement of ferritin concentration can be influenced by the presence of inflammation, we measured C-Reactive Protein (CRP) to ensure no inflammation. This was assessed by using an agglutination assay (Wampole Laboratories, Cranbury, NJ).

**Body Composition**

Fasting state hydrostatic weighing (1) was used to measure whole body density. For this test, residual lung volume was estimated via the nitrogen dilution technique (34) with the subject in the water. Fat-free mass (FFM) and percent body fat were estimated from body density using the two compartment model equation of Siri (29). At
weeks 1 and 13, each subject completed three consecutive 24-hour urine excretion collections. Urinary creatinine concentration was measured using the colorimetric Jaffe reaction (7) on a Technicon Autoanalyzer II (Technicon Instrument Corporation, Tarrytown, NY).

**Statistical Methods**

Values are reported as mean ± SEM. A normality test was first run on each variable at all 3 time points to determine whether data were normally distributed within each gender. If data were not found to be normally distributed, then the data for that variable were log transformed. A log transformation was necessary for transferrin saturation, ferritin, and transferrin receptor-ferritin ratio values. Analyses were then run on the log transformed data. A comparison of group mean values for all parameters measured at baseline was done by using a non-paired t test. A two-by-two repeated measures ANOVA with Supplementation as a between subject factor and Time as a within subject factor was performed. Because no differences were found within the men or the women as a result of the chromium picolinate or placebo supplementation, supplement groups were combined, and a two-by-two repeated measures ANOVA with Sex as the between subject factor and Time as the within subject factor was performed. All calculations were performed by using PROC t test and PROC GLM of SAS v. 6.11 (SAS Institute Inc., Cary, NC). The level of statistical significance was chosen to be $p < .05$ (two-sided). All data were processed by using Microsoft Excel 5.0 (Microsoft Corporation, Redmond, WA).

As previously stated, the data presented in this report were obtained retrospectively. The sample size was based on a priori statistical power tests of expected changes in variables unrelated to iron metabolism. The present sample size provides 80% statistical power to detect a difference on the order of 4/3 of a standard deviation using $p < .05$ (two-sided).

**Results**

Select physical and clinical characteristics of the study subjects are presented in Table 1. At baseline, the men were taller, heavier, had greater body density, greater FFM, greater urinary creatinine excretion, greater muscle strength, and lower percent body fat than the women. With resistance training, body density increased, FFM increased, percent body fat decreased, and urinary creatinine excretion increased in the men, but not the women (significant time-by-sex interactions, $p < .05$, except urinary creatinine excretion, $p = .06$). With resistance training, muscle strength increased by 23 ± 13% ($p < .0001$) in the women and by 20 ± 9% ($p < .0001$) in the men with no significant time-by-sex interaction.

Dietary energy and iron data from the 3-day food records are presented in Table 2. At baseline, the men consumed more total energy, total iron, and had a greater bioavailable iron intake than the women. Total iron density was lower, but bioavailable iron density was higher in the men versus the women at baseline. There were no significant changes over time or time-by-sex interactions for any of these dietary intake parameters.

Hemoglobin, hematocrit, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, red blood cell count, mean corpuscular volume, red blood cell distribution width, platelet count, and mean platelet volume were within
Table 1  Physical Characteristics, Skeletal Muscle Strength, and Body Composition of Older Men and Women Before and After 12 Weeks of Resistance Training (RT12)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Men</th>
<th></th>
<th>Women</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>RT12</td>
<td>Baseline</td>
<td>RT12</td>
</tr>
<tr>
<td>Age (years)</td>
<td>62 ± 1</td>
<td></td>
<td>61 ± 1</td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>175.9 ± 1.5</td>
<td></td>
<td>163.4 ± 1.2a</td>
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</tr>
<tr>
<td>Body weight (kg)</td>
<td>93.2 ± 2.6</td>
<td>93.3 ± 2.4</td>
<td>77.1 ± 1.9a</td>
<td>77.5 ± 1.9</td>
</tr>
<tr>
<td>Muscle strength (kg)</td>
<td>352 ± 12</td>
<td>419 ± 9b</td>
<td>213 ± 9a</td>
<td>262 ± 8b</td>
</tr>
<tr>
<td>Body density (kg/L)</td>
<td>1.022 ± 0.003</td>
<td>1.026 ± 0.002b</td>
<td>1.000 ± 0.001c</td>
<td>0.999 ± 0.002c</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>60.9 ± 1.7</td>
<td>63.0 ± 1.7</td>
<td>41.8 ± 1.0c</td>
<td>41.9 ± 0.9c</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>34.5 ± 1.2</td>
<td>32.4 ± 1.0</td>
<td>45.6 ± 0.7a</td>
<td>45.7 ± 0.9c</td>
</tr>
<tr>
<td>Urinary creatinine (g/day)</td>
<td>1.64 ± 0.05</td>
<td>1.92 ± 0.08</td>
<td>1.35 ± 0.05a</td>
<td>1.51 ± 0.06d</td>
</tr>
</tbody>
</table>

Note. Values are mean ± SEM.

aDifferent than men at baseline, p<0.05. bDifferent than baseline, p<0.05. Time-by-Sex interaction, 'p < .05. "p = .06.

Table 2  Dietary Energy and Iron Intakes of Older Men and Women Before and After 12 Weeks of Resistance Training

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Men</th>
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<th>Women</th>
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<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>RT12</td>
<td>Baseline</td>
<td>RT12</td>
</tr>
<tr>
<td>Energy (MJ/d)</td>
<td>9.28 ± 0.56</td>
<td>9.67 ± 0.45</td>
<td>7.54 ± 0.42a</td>
<td>7.55 ± 0.46</td>
</tr>
<tr>
<td>Energy (kcal/d)</td>
<td>2217 ± 133</td>
<td>2311 ± 108</td>
<td>1803 ± 101a</td>
<td>1805 ± 111</td>
</tr>
<tr>
<td>Total iron (mg/d)</td>
<td>14.5 ± 1.1</td>
<td>16.3 ± 3.6</td>
<td>14.4 ± 0.9</td>
<td>12.7 ± 4.2</td>
</tr>
<tr>
<td>Iron density (mg·1000 kcal⁻¹·d⁻¹)</td>
<td>6.6 ± 0.3</td>
<td>7.0 ± 0.3</td>
<td>8.3 ± 0.6a</td>
<td>7.1 ± 0.4</td>
</tr>
<tr>
<td>Bioavailable iron (mg/d)</td>
<td>0.91 ± 0.34</td>
<td>0.80 ± 0.07</td>
<td>0.52 ± 0.02b</td>
<td>0.44 ± 0.03</td>
</tr>
<tr>
<td>Bioavailable iron density (mg·1000 kcal⁻¹·d⁻¹)</td>
<td>0.40 ± 0.05</td>
<td>0.34 ± 0.04</td>
<td>0.30 ± 0.02a</td>
<td>0.26 ± 0.02</td>
</tr>
</tbody>
</table>

Note. Values are mean ± SEM; n = 15 men, n = 17 women.
Different than men at baseline: 'p < .05; "p < .001.
the normal range for men and women at baseline and did not change with resistance training (Table 3). White blood cell counts were within the normal range for men and women at baseline (6.0 ± 0.3 × 10⁶ cells/L (range 3.0–8.2 × 10⁶ cells/L) and 5.5 ± 0.2 × 10⁶ cells/L (range 4.1–7.2 × 10⁶ cells/L), respectively) and did not change with resistance training. Three women exhibited a positive response for C-reactive protein at baseline. C-reactive protein assessment was negative across all three time points for the other 13 women. Seventeen men exhibited a negative C-reactive protein across all three time points, while 1 man exhibited a positive result for all three time points. Examination of the ferritin values of the subjects exhibiting a positive C-reactive protein revealed no correlation between the two measures.

Table 3  Blood Biochemical Indices of Iron Status of Older Men and Women Before and After 12 Weeks of Resistance Training

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Men</th>
<th></th>
<th>Women</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>RT12</td>
<td>Baseline</td>
<td>RT12</td>
</tr>
<tr>
<td>Iron (µmol/L)</td>
<td>13.2 ± 1.3</td>
<td>12.0 ± 1.1</td>
<td>10.2 ± 0.9</td>
<td>9.7 ± 0.9</td>
</tr>
<tr>
<td>Total-iron-binding capacity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(µmol/L)</td>
<td>38.4 ± 2.2 b</td>
<td>27.3 ± 1.3 c</td>
<td>52.8 ± 3.5</td>
<td>55.2 ± 4.1 d</td>
</tr>
<tr>
<td>Transferrin saturation (%)</td>
<td>35.7 ± 3.8 b</td>
<td>45.4 ± 4.0 e</td>
<td>20.6 ± 2.2</td>
<td>20.8 ± 3.6 a</td>
</tr>
<tr>
<td>Ferritin (µg/L)</td>
<td>132.8 ± 22.5</td>
<td>125.4 ± 24.2</td>
<td>123.1 ± 24.2</td>
<td>97.0 ± 17.6 c d</td>
</tr>
<tr>
<td>Transferrin receptor (µg/L)</td>
<td>3.6 ± 0.3 b</td>
<td>4.9 ± 0.5 c</td>
<td>5.3 ± 0.4</td>
<td>5.3 ± 0.3 d</td>
</tr>
<tr>
<td>Transferrin receptor:ferritin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ratio</td>
<td>68.2 ± 30.4</td>
<td>117.6 ± 58.8 c</td>
<td>67.3 ± 11.7</td>
<td>133.1 ± 58.9 c</td>
</tr>
<tr>
<td>Hemoglobin (g/L)</td>
<td>155 ± 2 a</td>
<td>152 ± 3</td>
<td>134 ± 3</td>
<td>132 ± 4</td>
</tr>
<tr>
<td>Hematocrit</td>
<td>0.45 ± 0.01 b</td>
<td>0.45 ± 0.01</td>
<td>0.39 ± 0.01</td>
<td>0.39 ± 0.01</td>
</tr>
<tr>
<td>RBC (1012 cells/L)</td>
<td>5.0 ± 0.1 b</td>
<td>5.0 ± 0.1</td>
<td>4.5 ± 0.1</td>
<td>4.4 ± 0.1</td>
</tr>
<tr>
<td>MCV (fl)</td>
<td>90.0 ± 1.0</td>
<td>90.2 ± 1.0</td>
<td>88.8 ± 0.9</td>
<td>88.2 ± 0.9</td>
</tr>
<tr>
<td>MCH (pg)</td>
<td>30.7 ± 0.3</td>
<td>30.5 ± 0.4</td>
<td>30.2 ± 0.5</td>
<td>30.5 ± 0.4</td>
</tr>
<tr>
<td>MCHC (g/L)</td>
<td>341 ± 1</td>
<td>338 ± 2</td>
<td>340 ± 3</td>
<td>337 ± 3</td>
</tr>
<tr>
<td>RDW</td>
<td>0.13 ± 0.01</td>
<td>0.13 ± 0.01</td>
<td>0.13 ± 0.01</td>
<td>0.13 ± 0.01</td>
</tr>
<tr>
<td>Platelet count (10⁹/L)</td>
<td>253 ± 10</td>
<td>248 ± 8</td>
<td>284 ± 15</td>
<td>284 ± 14</td>
</tr>
<tr>
<td>MPV (fl)</td>
<td>8.1 ± 0.1</td>
<td>8.2 ± 0.2</td>
<td>8.0 ± 0.1</td>
<td>8.2 ± 0.1</td>
</tr>
</tbody>
</table>

Note. Values are mean ± SEM.

*Parameters include RBC, red blood cell (erythrocyte) count; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; RDW, red blood cell (erythrocyte) distribution width; and MPV, mean platelet volume. aMen different than women at baseline, p < .005. bWithin group, different than baseline, p < .05. cTime-by-Sex interaction, p < .05.
The indices of iron status data are presented in Table 3. At baseline, mean serum iron concentration was not different between the women and men (p = .066). Also at baseline, total iron binding capacity was higher (p < .005), transferrin saturation percent lower (p < .005), ferritin concentration not different, and transferrin receptor concentration higher (p < .005) in the women, compared with the men. Mean serum iron concentration did not change in the men or women with resistance training. For the women, TIBC did not change with resistance training, while the men experienced a significant decrease in TIBC (p < .0001). Transferrin saturation (TfSat) was not changed in the women over time but increased in the men (p = .006). When comparing the men and the women, a Time-by-Sex interaction was indicated for TIBC (p < .01). The TIBC of the women increased by 8.3 ± 9.6% (nonsignificant) and that of the men decreased by 26.0 ± 4.5% (percent changes were calculated individually and then the overall mean was calculated). Transferrin saturation (TfSat) responses subsequently exhibited a Time-by-Sex interaction (p = .02; Table 3). The TfSat of the women were unchanged (0.4 ± 10.0%; percent changes were calculated individually and then the overall mean was calculated), while that of the men increased by 35.1 ± 10.7%. Mean serum ferritin concentration decreased significantly over time (p = .03) for the women and therefore was lower at resistance training week 12, compared with baseline. The men did not experience a significant change in serum ferritin concentration over time. Therefore, a Time-by-Sex interaction was observed for serum ferritin concentrations, with the decrease observed in the women being about 3.5 times that seen in the men (24.1 ± 8.0% vs. 7.2 ± 6.6%, respectively). Mean transferrin receptor concentrations did not change in the women over time, while they increased significantly in the men (p = .03). Thus, the changes in transferrin receptor concentration were different for the men versus the women. However, for both the women and men, the mean ratio of the serum transferrin receptor to ferritin was increased over time (67.3 ± 11.7 at baseline and 133.1 ± 58.9 at resistance training week 12 for women; 68.2 ± 30.4 to 117.6 ± 58.8 from baseline to resistance training week 12 for men; p = .01).

Discussion

Iron deficiency is the most frequent nutritional deficiency disorder in the world. Populations generally recognized for being at risk for developing iron deficiency are infants, adolescent girls, and pregnant women (4). However, iron deficiency is also likely prevalent among the geriatric population due to a combination of factors. Some of these factors include chronic diseases, normal physiological changes that occur with aging, and malnutrition (16). Reports regarding iron deficiency caused by exercise have also received much attention (17, 23, 25).

The present study is the first to examine the effects of resistance training by older, postmenopausal women on iron status and to compare these effects with those in older men using the exact same relative intensity resistance training program. The twice weekly resistance exercise program was chosen to fit within the American College of Sports Medicine guidelines (2) for inclusion of resistance training in an exercise program for adult fitness, and was demonstrated to be effective by the significant increases in muscle strength in both the men and women (Table 1).

When determining the effects of resistance training on iron status, it is very important to perform a dietary analysis to determine whether iron intake changed over time. If this is not determined, then it is difficult to conclude whether changes in
Iron status occurred as a result of the exercise or dietary modification. Although dietary iron intake is important to determine, Carpenter et al. (10) suggested that dietary iron bioavailability is a much better indicator of actual iron intake as well as nutritional adequacy. For this reason, we determined the bioavailability of the iron consumed by each individual as this is the only iron that would have any affect on iron status. The amount of bioavailable iron ingested by the women was rather low. This low intake was most likely due to the large daily intake of tea (which contributes to the inhibition of iron absorption) by the women in this study. The men consumed a higher amount of bioavailable iron than the women, although neither the men nor the women had a significant change in bioavailable iron consumption throughout the study. Since all subjects continued to consume their habitual and self-selected diets, and the results of the 3-day food records did not indicate any major changes in the diets during the study, we can be confident that any changes seen in iron status are related to the exercise program and not dietary intake.

In the present study, the postmenopausal women showed a significant decrease in mean serum ferritin concentration coupled with a trend upward in TIBC by resistance training week 12, suggesting a compromise in iron stores. However, mean serum iron concentration, transferrin saturation, and transferrin receptor concentration for these women remained unchanged. These results are consistent with findings in young men reported by Schobersberger, Spodaryk, and Lukaski (19, 27, 31), but are different from the older men who completed the same study protocol (8).

Given our findings with respect to changes in ferritin concentration, we expected to observe an increase in the mean transferrin receptor concentration of the women and no change in this parameter for the men. What we observed, however, was the opposite. Several possible explanations exist. The women’s mean transferrin receptor concentrations were significantly higher than those of the men at baseline. Although the women’s mean transferrin receptor concentration did not increase, it was still higher than that of the men at resistance training week 12, indicating that it may have already been upregulated. The men, on the other hand, had a lower mean transferrin receptor concentration at baseline which increased with resistance training due to upregulation of the receptor. Although this may explain the reason that we did not observe an increase in transferrin receptor concentration of the women, it seems puzzling that the men’s mean transferrin receptor concentration increased given the response of the other iron status parameters.

The observed increase in FFM, consistent with an increase in muscle mass that occurred in the men, may explain the increase in the transferrin receptor concentration. Serum transferrin receptor concentration reflects functional iron status in tissues (30) and appears to be most influenced by total erythropoietic activity (5, 14, 18). Therefore, as FFM (muscle mass) increases, we would expect to see an increase in transferrin receptor concentrations as the tissue’s iron requirements are elevated. Anttila et al. (3) followed pubertal development in healthy boys and evaluated changes in body iron stores by calculating the serum transferrin receptor-ferritin ratio. They found that as the boys experienced growth of body and muscles, the transferrin receptor–ferritin ratio increased significantly. Because the older men in our study experienced an increase in FFM (Table 1), the transferrin receptor concentrations may have been increased in order to meet the tissue’s iron requirements. The changes that we observed in the transferrin receptor-ferritin ratio in these men support this conclusion and are similar to the changes observed by Anttila et al. (3). In the present study, the transferrin receptor-ferritin ratio increased significantly.
(p = .01) in the men from baseline to resistance training week 12; this is consistent with increased growth rather than iron deficiency.

The women in the present study experienced no change in FFM and no detectable change in the transferrin receptor concentration (Tables 1 and 3, respectively). It may be that the muscle mass increase experienced by the women was not great enough to elicit a detectable response by the transferrin receptor assay. The cancer literature provides a corresponding analogy. Raff et al. (26) examined serum transferrin receptor levels in patients with breast adenocarcinoma. They found no significant difference in transferrin receptor concentrations of control women and women with invasive adenocarcinoma of the breast despite knowing that actively growing tumors express large amounts of transferrin receptor. The women in their study may not have had sufficient tumor bulk to induce a sufficient rise in serum transferrin receptor concentration. Similarly, the lack of change in FFM in the women in the present study may not have provided the stimulus to elicit a rise in transferrin receptor concentration.

The findings in our older men are different from findings in younger men undergoing resistance training. Schobersberger et al. (27) and Lukaski et al. (19) assessed the effects of resistance training on iron status of young men, while Campbell et al. (8) studied the effects in older men. Schobersberger et al. reported that 6 weeks of resistance training by young men decreased hemoglobin, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration. They also reported a decreased serum ferritin concentration, while serum iron, TIBC, and transferrin saturation were unchanged. Lukaski et al. found a decrease in serum ferritin concentration, an increase in TIBC, and a decrease in transferrin saturation with resistance training. Serum iron concentration, hemoglobin concentration, and hematocrit were unaltered. Spodaryk (31) conducted research in male Olympic strength trained athletes, male endurance-trained athletes, and male untrained controls. He reported a decreased serum ferritin concentration for the strength trained men compared to the untrained control men. No significant differences were found between the two groups for changes in hemoglobin concentration, hematocrit, serum iron concentration, TIBC, and transferrin saturation. These three studies suggest that RT by young men deleteriously alters iron status. These results, however, are not consistent with our previous findings in older men (8), which suggest a change in iron transport that is opposite to changes associated with iron depletion.

The only study to date that reports the iron status effects of anaerobic exercise by women was conducted by Magazinick et al. (20). They reported the effects of 7 weeks of highly intense anaerobic as well as aerobic exercises by young women. This study showed that the women experienced a decreased serum iron concentration, increased TIBC, decreased serum ferritin concentration, decreased red blood cell concentration, and decreased hematocrit as a result of the exercise. The women in our present study also exhibited a decreased serum ferritin concentration.

Although we do not know the exact mechanisms causing the change in the iron indices of our subjects, there is a clear difference in the way that postmenopausal women respond to resistance training compared to older men.

**Summary and Conclusion**

The present study shows a significant decrease in mean serum ferritin concentration coupled with a trend upward in TIBC for older, postmenopausal women undergoing
resistance training. This suggests the possibility for compromised iron stores in women undergoing resistance training. This does not hold true for the men in this study. We show that resistance training causes changes in iron status of older men that are opposite to changes associated with iron depletion. We also show that during body growth, elevated serum transferrin receptor concentrations may reflect growth rather than iron deficiency, as evidenced by the men in this study. A study of longer duration is needed to determine whether the iron status of women will fall to below normal levels with long-term resistance training. Considering our findings, it is very important to ensure adequate bioavailable dietary intake of iron by older, postmenopausal women undergoing resistance training to prevent the possibility of iron deficiency.

References


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