Resting Metabolic Rate and Body Composition Change in Women Following Different Exercise Training Programs

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Abstract

Purpose: The purpose of this study was to evaluate Fat Free Mass (FFM) and Resting Metabolic Rate (RMR) changes in women after a 12 week Resistance Training (RT) or Concurrent (combined endurance and resistance) Training (CT).

Methods: Eighteen women (36-61 years old) were randomized to a RT or CT group that trained three times per week. Both groups participated in resistance training workouts with the CT group also participating in 30 minutes of moderate intensity cardiovascular exercise. Pre-and post-test FFM were calculated using a 3-site skinfold technique. Pre-and post-test RMR were measured in a fasted state.

Results: Significant increases (mean ± SE) in FFM (1.5 ± .7 kg, \( p = 0.045 \)) and RMR (77.4 ± 26.1 kcal, \( p = 0.01 \)) were found for the entire sample (RT and CT groups). No significant between group differences in FFM \( (p = 0.30) \) or RMR \( (p = 0.62) \) were found. Additionally, no significant group by time interactions were found for the FFM and RMR analyses \( (p = 0.85 \) and \( p = 0.41, \) respectively). FFM and RMR change scores were strongly correlated \( (r = 0.68, p < 0.01) \).

Conclusion: Results indicate that FFM and RMR significantly increased among women in this sample after 12 weeks in a RT or CT exercise program. Neither training modality (RT or CT) was superior in eliciting RMR or FFM changes in this study.

Keywords

Concurrent Training; Fat Free Mass; Metabolism; Resistance Training

Introduction

Data from the 2011-2012 National Health and Nutrition Examination Survey (NHANES) indicated that 33.9% of adults are overweight, 35.1% are obese, and 6.4% are extremely obese. Because obesity is a recognized risk factor for CVD, it is imperative to look closer into the potential benefits of Resistance Training (RT) as it has shown to improve body composition. By increasing Fat Free Mass (FFM) and reducing adipose tissue, RT has a supporting effect on increasing basal metabolic rate through increasing lean body mass [1]. Skeletal muscle is the primary means of glucose and triglyceride disposal as well as the major determinant of Resting Metabolic Rate (RMR). Considering that RMR and physical activity related energy expenditure account for approximately 90% of total energy expenditure, interventions which increase both components are potentially beneficial to preventing or reversing increases in adiposity [2]. Resistance exercise contributes to reduced cardiovascular risk through a decrease in metabolic risk factors, decreased adiposity, and increased RMR [3].

Substantial evidence indicates that FFM is highly related to RMR and total energy expenditure [4-12]. In addition, individuals who participate in physical activity have been shown to have a higher RMR and a lower percent body fat than sedentary individuals [3]. Cross sectional studies have shown that muscular strength is inversely related to all-cause mortality, CVD-related mortality, and the metabolic syndrome [13-15]. Epidemiological evidence further supports resistance exercise in the prevention of age related weight and fat gain [16-18]. Despite these relationships, investigations examining the effects of resistance training on RMR have reported inconsistent results [2]. Studies examining the effects of
resistance and endurance training together (CT) and separately have shown inconsistent results in regards to physiological change related to RMR [2,3,19-23]. In women, there are few investigations of training programs effect on RMR and results are conflicting [3,19,24-26]. Results of studies examining the effect of endurance training on RMR have been equivocal. Most research focused on exercise and RMR has examined short-term effects of physical exercise on RMR rather than on potential long-term effects [27]. Several investigations have shown increases in RMR following training [20,23,25] while others have shown no effect or decreases in RMR [2,3,19,22,26]. Although many factors may affect RMR, it is most heavily influenced by FFM [4-12,28]. Therefore, interventions aiming to increase FFM are proposed to increase RMR [22]. Considering endurance exercise produces minimal gains in FFM when compared to resistance exercise, it would seem that individuals who participate in just endurance activities would have lower FFM and ultimately a lower RMR [21].

Studies evaluating changes in RMR following a training program have shown inconsistent results [2,3,19-27,29,30]. It is unclear when the effect of an exercise bout ends and when an elevated RMR may be interpreted as a chronic adaptation attributed to physical fitness. Additionally, it is unknown how long it takes an individual participating in a program to see the training effects of increased RMR at rest. While evidence suggests RT increases FFM and subsequently RMR, results from several studies among women do not support this finding. Poehlman et al., [29] suggested that no chronic changes in RMR are seen following a resistance training program and that RMR increases are primarily derived from the direct cost of energy. Other studies show significant increases in RMR to be attributed to FFM [20,23] while others show increases in RMR after controlling for FFM [3,25,30].

Considering previous inconsistent findings, additional research is warranted, specifically in women, to evaluate the effects of training on FFM and RMR from two different training regimens: 1) RT only, and 2) CT. Therefore, the purpose of this study was to examine RMR and FFM changes resulting from RT and CT in women.

Methods

Participants

Participants were 18 women, 36-61 years old, recruited through an email listserv sent to the staff and faculty of an upper Midwest university. The study was approved by the university Institutional Review Board. Informed consent and PAR-Q forms were completed prior to participation. If a participant answered “yes” to any of the six questions on the PAR-Q, additional physician’s consent was required for participation. Participants were excluded if they had any of the following: physical or psychological diseases which would hinder their abilities to perform requested resistance and endurance training and testing, a previous cardiac event, or if they were unable to receive physician consent if required. All relevant medications were recorded.

Protocol

After signing informed consent forms and receiving physician’s consent if needed, participants completed a battery of fitness tests. Participants were given precise instructions regarding these tests prior to coming to the testing facility and were asked not to engage in physical activity beyond their basic daily activities for 24 hours prior to initial testing. Prior to testing, individuals were instructed to wear comfortable, loose fitting clothing consistent with testing, drink plenty of fluids to ensure proper hydration, avoid food, tobacco, alcohol, and caffeine for at least 3 hours before testing, avoid exercise or strenuous physical activity the day of the test, and get an adequate amount of sleep (6-8 hours) the night before the testing. Following pretesting, volunteers were randomized into either a control (resistance training) or intervention (concurrent training) group. The intervention group engaged in a Concurrent (CT) exercise training consisting of 12 weeks of progressive aerobic and resistance exercise three days a week totaling 60 minutes per session. The control group (RT) participated in the same resistance training program, but without the aerobic exercise for a total of 30 minutes. The battery of assessments was taken prior to intervention and was then repeated after 12 weeks of training.

Experimental procedures

Weight was measured by a calibrated electric scale (Detecto® DR450, Daugherty Webb City, MO). Body composition was measured using a Lange skinfold caliper (Beta Technologies, Santa Cruz, California) at the triceps, suprailliac, and thigh. Jackson-Pollock three-site equation was used to calculate body fat percentage. Body composition as determined from skinfold measurement has been shown to correlate well with hydrostastically determined body density and to be both reliable and valid [31]. FFM was determined using the subject’s weight and body fat percentage.

Resting Metabolic Rate (RMR) was measured through the use of a Medgraphics® metabolic cart (UltimaTM CPX, St. Paul, MN) using Breeze Suite software. This measurement was done on a pre-post basis within a minimum of 72 hours from their last training or testing session. Participants were scheduled in the early morning after having fasted for a minimum of 10 hours to have their RMR measured. Participants were asked to lay supine on a cushioned table and rest for the necessary 30 minutes prior to testing RMR. After lying supine for five minutes, resting systolic and diastolic Blood Pressure (BP) was measured using an automated sphygmomanometer (GE Dinamp Carescare v100, Waukesha WI) which has been previously validated [32]. Breath-by-breath gases were collected for a 20 minute period. Volume oxygen and volume carbon dioxide from the test period was used to calculate RMR using the abbreviated Weir equation [33].

A Three Repetition-Maximum (3RM) protocol was used to estimate maximum upper and lower body strength. The 3RM method has been shown to provide valid estimates of 1RM strength [34]. Participants performed a 5-minute light treadmill warm-up and...
prior to the 3RM strength assessments. Upper body strength was tested with the barbell bench press. The same 3RM procedures were used to test lower body strength using a hip-sled. For each 3RM assessment, a warm-up set was given followed by gradually increasing resistance until the participant could no longer complete three repetitions. A timed two minute rest was given between attempts.

**Treatment groups**

Resistance Training (RT) consisted of the following eight machine and free weight exercises for the main muscle groups: leg press, chest press, shoulder press, seated row, dumbbell deadlift, lunges, and a core exercise. For each exercise, volume began at 12 repetitions for each set and progressed from two sets the first two weeks to three sets the third week. In the fourth week, if participants could complete more than 12 repetitions for a specific exercise load was increased maintaining a repetition range fatiguing between 8-12 repetitions and continuing with three sets. Intensity and exercises were monitored and progressed based on individual development. As individuals progressed, additional weight and more advanced exercises were added to the program.

The Concurrent Training (CT) group completed the same resistance training exercise program as described for the RT group and an additional cardiovascular training component. Immediately following completion of the resistance training, heart rate monitored aerobic exercise was performed using a treadmill by the CT group. Age predicted (220-age) Heart Rate max (HR max) was used to determine the individual’s exercise intensity. Aerobic exercise was monitored by Polar® heart rate monitors and began at 60-75% HR max. In the third week, intensity was assessed and increased to 75-90% HR max.

**Statistical analysis**

Independent samples $t$-tests were used to compare baseline characteristics between groups. Two-factor (group x time) repeated measures Analysis of Variance (ANOVA) was used to evaluate treatment effects and time-related changes in FFM and RMR. The relationship between FFM and RMR change scores was evaluated using a Pearson correlation. Alpha was set < 0.05 for all analyses. Data was normally distributed, as assessed by Shapiro-Wilk’s test $p < 0.05$.

**Results**

Initial subject characteristics were not found to be significantly different by group $p < 0.05$. Table 1 represents subject characteristics pre and post training by group.

|                        | RT Group |             | CT Group |             |
|------------------------|----------|-------------|----------|-------------|
|                        | Pre      | Post        | Pre      | Post        |
|                        | Mean     | SD          | Mean     | SD          |
| Age                    | 52.13    | 7.26        | 48.82    | 7.08        |
| Height (cm)            | 167.16   | 5.67        | 166.7    | 7.42        |
| Weight (kg)            | 79.56    | 14.27       | 79.27    | 17.70       |
| Body Fat (%)           | 31.97    | 8.32        | 29.93    | 6.40        |

**Table 1:** Subject characteristics pre and post training.

Note: RT = Resistance Training only Group; CT = Concurrent Training Group

Participant groups were not significantly different at baseline in FFM ($p = 0.56$) or RMR ($p = 0.56$). No significant between group differences in FFM ($p = 0.30$) or RMR ($p = 0.62$) were found. Significant increases (mean ± SE) in FFM (+1.5 ± 0.7 kg, $p = 0.045$) and RMR (+77.4 ± 26.1 kcal, $p = 0.01$) were found from pre- to post-test when combining groups. Individual and combined group characteristics can be found in table 2. Figure 1 represents changes in RMR and figure 2 represents changes in FFM by group from pre to post training.

|                        | Pre      | Post    | Pre      | Post   |
|------------------------|----------|---------|----------|--------|
|                        | Mean     | SE      | Mean     | SE     |
| RMR (kcal/day)         | 1379.1   | 69.5    | 1476.7   | 73.9   |
| FFM (kg)               | 50.3     | 1.9     | 51.7     | 2.3    |

**Table 2:** Change in dependent variables pre to post training by group.

Note: RMR = Resting Metabolic Rate; FFM = Fat Free Mass; CT = Concurrent Training; RT = Resistance Training. *$p < 0.05$
Figure 1: Changes in resting metabolic rate pre to post training by group. CT represents concurrent training and RT represents resistance training.

Figure 2: Changes in fat free mass pre to post training by group. CT represents concurrent training and RT represents resistance training.

No significant group x time interactions were found for the FFM ($p = 0.54$) and RMR ($p = 0.41$) analyses. FFM and RMR change scores were highly correlated ($r = 0.68$, $p < 0.01$) as seen in Table 3.

|                  | FFM   | RMR   |
|------------------|-------|-------|
| FFM Change       | Pearson Correlation | 1     | 0.681* |
| Sig. (2-tailed)  | <0.01 |
| N                | 18    | 18    |
| RMR Change       | Pearson Correlation | 0.681* | 1     |
| Sig. (2-tailed)  | <0.01 |
| N                | 18    | 18    |

Table 3: Correlation between FFM and RMR change scores. *Correlation is significant at the <0.01 level (2-tailed)

Discussion

This study shows that resistance training and concurrent training result in a significant increase in FFM and RMR in women. One training method, however, was not shown to be superior to another in increasing FFM or RMR. While both groups completed the same resistance training program and both increased similarly in FFM, the mean increase of the CT RMR (+97.6 kcal) was nearly two times greater than the RT group (+52.25 kcal). This difference in change of RMR or between groups, however, was not shown to be statistically significant. These changes are illustrated in figures 1 and 2. If the trend continued and a larger sample size was provided, the CT may have had a significantly larger increase than that of the RT group. Considering the significant increases FFM and RMR when combining groups, each group may have also shown significance if presented with a larger sample size.

Studies including both men and women have shown similar results.
to those seen in our study of women. A study by Hunter et al., [23], examines RT, RMR, and Total Energy Expenditure (TEE) in older adults. Following a 26 week RT program, results showed increases in strength, FFM, RMR, and TEE. Increases in TEE were found to be a result of both increased RMR and physical activity. Campbell et al., [20] also assessed the changes in a similar population resulting from a 12 week progressive training program. Results showed RMR increased by 6.8%, however, similar to our study when expressed relative to increases in FFM the increase was not significant. Prately et al., [30] also showed consistent results following a 16 week RT program in men. Participants showed increases in strength, FFM, and RMR increased by an average of 7.7%. In this study, RMR changes correlated at baseline with FFM, however, after training a disproportionate increase was seen in RMR.

While studies grouping men and women together show significant results, those with only women are less consistent. A similar study conducted by Byrne and Wilmore [19], examined RMR changes in women during RT and a combination of RT and Walking (RTW). In contrast to our study, there were significant increases in FFM in both groups as a result of the training program. However, despite a similar increase in FFM by both groups, the RT group showed a significant increase in RMR while the RTW group showed a significant decrease. These results are different from our study in that the CT group showed a higher increase in RMR than the RT only group. A study by Ryan et al. [25], studied RMR changes in women following a 16 week RT and Weight Loss (RTWL) or RT only program. Results showed that the resistance training attenuated loss of FFM in the RTWL group and there was no change in RMR despite an average 5kg loss in weight. Increases in FFM and RMR were seen in as well as a decrease in percent fat in both groups. While weight loss in our study was minimal, similar to Ryan et al., [25], increases in FFM and RMR were seen.

Contrary to our results, several studies show no increase in RMR among women following a RT program. Taaffe et al., [26] studied RMR changes following 15 weeks of either a low intensity or high intensity RT program in older women. Muscle strength increased in both groups, fat mass decreased in the low group and there was a trend for FFM to increase in the high group. Despite the increase in FFM, no change occurred in either group for RMR. Participants were encouraged to continue the program for an additional 37 weeks and were re-evaluated. During this time period, strength increased further, however, no change was still seen in RMR for both groups. Similar results were found for women in a study by Lemmer et al., [2] that examined age and gender differences in response to RT and changes in RMR and energy expenditure of physical activity. When pooled together, men and women showed an absolute increase of RMR of 7%, similar to other mixed gender studies. When groups were split by gender however, neither young nor older women showed significant increases in absolute or relative RMR in response to the training program. Poehlman et al., [24] examined TEE in women over a six month program of either endurance training or RT. Increases in FFM and RMR were seen in only the RT group, however, no significant or chronic change was seen in either group for TEE indicating increases in energy expenditure was attributed to the activity itself.

An important outcome of this study was that CT was not found to have a negative effect on increases in FFM and RMR. Rather the CT group had a higher increase in RMR than the RT group, although not significant. Effects of endurance training on RMR are controversial, however, evidence seems to suggest that this increase may be due to increases in rate of activity per kilogram of tissue. This increase in activity may be due to increased activity of enzymatic reactions, increased substrate flux, repair of exercise-induced trauma, increased concentrations of metabolic hormones, replenishment of glycogen stores, and increases protein synthesis [3,35]. Several studies have shown an increase in RMR following training after controlling for FFST suggesting that increases in RMR are not solely due to increases in RMR and may be sympathetically mediated. This increase in Sympathetic Nervous System (SNS) activity has been shown in men [3,29,30,36,37] but not in women [25]. While not significant, the greater increase in RMR seen in the concurrent training group may have been mediated through these mechanisms. Unfortunately, SNS activity was not measured in this study we cannot definitively say this was a contributing factor to the increased, but insignificant, RMR seen in the CT group.

Further insight on why the group that participated in aerobic training had a higher RMR may be similar to a study by Ballor and Poehlman [3] that examined the difference between resistance training and aerobic training in women regarding RMR. Regular exercise of both types was associated with higher RMR compared to the sedentary group. When adjusted for FFM the aerobic group had a significantly higher RMR than did the sedentary group. While not significant, when adjusted for FFM change the CT group in our study was also higher than the RT group. The results of RMR differences between groups support a similar study by Poehlman et al., [29] that found both the aerobic and resistance training groups to have higher RMR than the sedentary group with the aerobic being the highest. This evidence as well as this current study suggest that the mechanisms by which aerobic and resistance training increase RMR are different, making it sensible to include both in a concurrent program when looking to maximize the benefits and increasing RMR.

**Conclusion**

In this study, both training programs exerted a positive effect on both FFM, and RMR, which may assist in weight management and maintenance of body composition. Results indicate that FFM and RMR significantly increased among women in this sample after 12 weeks in a RT or CT exercise program. Neither training modality (RT or CT) proved superior in eliciting RMR or FFM changes in this study. Furthermore, CT did not negate improvements in FFM and RMR. Evidence is limited with only one other study to our knowledge comparing a RT and CT training in women. The majority of current studies examine both men and women combined in an intervention and fail to examine each group separately. Current understanding would not lead us to expect the addition of cardiovascular training to a resistance program to increase RMR as cardiovascular training alone does not show to increase FFM. Our study however found that the CT group had an increase of nearly twice as much as the RT group. Further
investigation is needed to determine the mechanisms in which cardiovascular exercise leads to additional increases in RMR in women.

Grants

Funding for support of this research was provided by the Department of Health Nutrition and Exercise Sciences and the College of Human Development and Education at North Dakota State University.

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