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Six Weeks of Moderate Functional Resistance Training Increases Basal Metabolic Rate in Sedentary Adult Women

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ABSTRACT

International Journal of Exercise Science 11(2): 32-41, 2018. Basal metabolic rate (BMR) is a significant contributor to total daily energy expenditure. Traditional resistance exercise has been shown to elicit fat free mass (FFM) related increases in BMR. The purpose of this study was to examine the effect of a functional resistance exercise program on the BMR of a group of previously sedentary adult women in a free-living condition. 19 sedentary, apparently healthy women underwent body composition analysis and had BMR assessed before and after a 6-week functional resistance training program. The resistance training program was designed to be progressive in volume and intensity, and to be achievable for novice exercisers. Following exercise training, BMR significantly increased (+246.76Kcal*day^{-1} ± 231.48, t=4.64, $p<.001$), while no changes were observed in percent body fat, FFM, fat mass (FM), or BMI (all $p>.05$). There was also a modest increase in total mass (+0.63 ± 0.87 Kg t=3.16, p=.005). Results from this study suggest that 6 weeks of functional, progressive, resistance exercise can elicit significant improvements in BMR in previously sedentary adult women; but does not elicit significant changes in body composition, FFM, or FM.

KEY WORDS: Metabolism, exercise, daily caloric expenditure

INTRODUCTION

A person's BMR is the energy utilized to maintain homeostasis at rest; excluding the influences of physical activity, diet induced thermogenesis, emotional stress, or any other stimulus resulting in an increase in sympathetic activity (15). BMR is a significant portion of total daily energy expenditure, but is dependent on a number of physiological factors such as total mass (18, 27, 29), body surface area (14), and age (21). BMR has also been found to be predictive of bone mineral density in older women (16). In recent years, researchers have attempted to use diet and exercise as a method of altering BMR (1, 10, 13). Many of these studies aim to use diet and exercise as a method for reducing total mass while preserving, or increasing, FFM. FFM and total mass have both been independently linked to BMR; however, recent evidence suggests that preservation of FFM may not be sufficient to preserve BMR during a period of sustained weight loss (17, 19). Furthermore, the reduction in BMR has been observed to be disproportionate to the reduction in total mass. Bonfanti et al. (6) compared the effects of a

Mediterranean diet and a diet rich in complex carbohydrates, with and without exercise, on body composition and BMR in a sample of 36 subjects with metabolic syndrome. Results from this study indicated that exercise improved weight loss in both groups, but also elicited a reduction in BMR. However, the complex-carbohydrate rich diet was able to preserve BMR more than the other diet groups, highlighting the importance of appropriately combining diet and exercise during weight loss. While these studies have used hypocaloric diets and exercise to induce weight loss and preserve BMR, other research has examined resistance exercise as a method for increasing BMR.

In contrast to aerobic exercise, resistance training is generally considered to promote BMR. A single session of high intensity resistance exercise has been shown to elicit a temporary increase in BMR for up to 48 hours following exercise (32). This transient increase in BMR is likely mediated by elevations in protein turnover and general recovery from exercise. Other long-term resistance training studies have observed a more permanent increase in BMR, with concurrent increases in FFM in older men (26), and moderately obese women (9). However, there is evidence to suggest that increases in FFM may not be the primary mechanism for strength-training induced increases in BMR (1, 28). This is well illustrated by both Pratley et al. (26) and Lazzer et al. (19) who reported disproportionate changes in BMR in relation to changes in FFM. Furthermore, variability in dietary intake (i.e. a Mediterranean diet vs. a diet high in complex carbohydrates) can differentially affect BMR. This warrants future research exploring the optimization of personalized fitness programs for promoting BMR in the general population.

The projects mentioned previously use highly structured and traditional exercise programs (aerobic and anaerobic) combined with strict dietary protocols to elicit changes in body mass and therefore BMR. While these studies provide very detailed insight on the potential mechanisms influencing changes in BMR and report significant improvements related to weight loss, there is a void of research with a high degree of external validity and applicability to the non-exercising general population. It is estimated that only 21% of American adults (ages 18-64) meet the 2008 physical activity guidelines (150 minutes per week of moderate to vigorous physical activity), and that women are less likely than men to meet these guidelines (CDC, 2012). Therefore, the purpose of this project was to test the effect of a 6-week functional resistance training program (a resistance training program focused on non-traditional, multi-joint movements that mimic activities of daily living) on BMR, total mass, FFM, FM, and BMI in a group of previously sedentary and apparently healthy adult women. This exercise program was designed to be suitable for at-home use, and to represent an achievable and sustainable resistance exercise program for a sedentary adult in the contemplation stage of the "stages of change model" of behavioral change. We hypothesized that BMR and FFM would significantly increase following exercise training, but total mass, BMI, and FM would not change.

METHODS

Participants

An *a-priori* power analysis was performed using G*Power (3.1.4) software. Based on an estimated effect size of *d*=0.67 (derived from pilot data) with a desired power of 1-β=0.08 (alpha set *a-priori* to p=0.05), 20 subjects were initially recruited. One subject dropped out during the training phase, resulting in 19 subjects being included in the final analysis. All participants were previously sedentary adult women with no cardiovascular, respiratory, or metabolic diseases. All women were classified as either low or moderate risk according to the standards set by the American College of Sports Medicine (ACSM). The average age of the study sample was 48years ± 5, the average height was 163.71cm ± 7.48, the average weight at baseline was 72.36Kg ± 12.61, and the average BMI at baseline was 26.96Kg*$(m^2)^{-1}$ ± 5.83.

This study followed a single-group, pre-post, quasi experimental design; and was completed between February and May of 2014. Participation included 2 visits to the physiology laboratory separated by 6 weeks of twice weekly supervised exercise sessions. This study protocol was approved by the Indiana University of Pennsylvania Institutional Review Board and conformed to the standards set forth by the Declaration of Helsinki.

Protocol

Subjects arrived at each assessment session (pre and post) at least 8 hours post-prandial and having abstained from exercise for at least 24 hours. Each assessment session was performed in a quiet room free of visitors and nearby foot traffic. In the first session, subjects were familiarized with the study protocol and consented. Next, body fat was assessed via air displacement plethysmography (BodPod, COSMED, Chicago, IL). This assessment required subjects to be fitted into a Lycra body suit and skull cap and remain still throughout the entire assessment period. Two measurements were taken consecutively and the average of those two measurements was recorded. Body Fat percentage (%BF), total mass (KG), FM, and FFM were all reported from this assessment. This was followed by the assessment of BMR.

There are a few different methods for accurately assessing energy expenditure in humans; the gold standard of which is the doubly-labeled water method. The doubly-labeled water method uses non-radioactive isotopes and has been used extensively in the general population (11) and wild animals (22) as a measure of “free-living” metabolic rate (in other words, average total daily energy expenditure). However, this method carries a significant participant burden (repeated follow-up visits) and may not be ideal for assessing energy expenditure in a resting state. Therefore, indirect calorimetry is often used to assess basal metabolic rate (3, 4, 20). Indirect calorimetry uses an open-circuit spirometry system to calculate energy expenditure via expired gas analysis. Specifically, this system collects expired air and analyzes it for relative Oxygen (O_2) and Carbon Dioxide (CO_2) content. Total body oxygen consumption (VO_2) can then be calculated by identifying the differences between inspired and expired O_2 and CO_2. Oxygen consumption is then used to calculate caloric expenditure (Kcal), and estimate basal metabolic rate. In this study, subjects were instructed to lay supine on a cot while BMR was collected through a clear-ventilation hood for 30 minutes (ParvoMedics TrueOne 2400 Metabolic Measurement System, Sandy, UT). The first 15 minutes of data was discarded and the last 15 minutes were averaged and reported. The BMR assessment concluded the second (post) laboratory session.

In the first (pre) session, subjects were given the opportunity to eat (either an orange or a banana provided by the investigators, or to eat food they brought with them) and drink water before performing a functional strength assessment as a substitute for a 1 repetition maximum (1RM). This functional strength assessment was developed for the purposes of this study only and has not been reported elsewhere. This assessment required subjects to perform each exercise (exercises are described below) at least 3 times with different weights while reporting rating of perceived exertion (RPE). Once an RPE of 12 or 13 was established for a specific weight it was recorded as the starting resistance for that specific exercise. A traditional 1RM protocol was not used in this study for two reasons. First, many of the exercises used did not conform to traditional 1RM assessments; and second, using RPE provides a measure of intensity with high degree of external validity. The first session concluded once a starting resistance load was assigned to each of the exercises (7).

Resistance Training Program: Subjects in this study participated in a 6-week exercise program that included 2 supervised exercise sessions per week, each lasting approximately 60 minutes. This exercise program was designed to be functional; meaning that the exercises are multi-joint compound movements that mimicked activities that might be performed in daily life (i.e. lifting, carrying, etc.). This exercise program was also designed to use devices that can be easily purchased and transported, making them accessible for the general population. Each of these exercise sessions were held in a private aerobics room housed in the James G. Mill fitness center located in the Indiana University of Pennsylvania Department of Kinesiology, Health, and Sports Science. Each session was led by one of two investigators. Both investigators were educated in the field of exercise science, and had experience in personal training and group exercise instruction. The overseeing investigator held the Health and Fitness Specialist certification through ACSM. Blood pressure and heart rate were recorded at the beginning of each session, followed by a 5-minute warm up that consisted of marching in place, unilateral reaches (unweighted), and side-step lunges (unweighted). The warm-up was followed by the exercise protocol.

The exercise performed were, in order, a front squat, overhead press, bent-row, trunk twist, side-step squat, chest raise, dumbbell row, bicep curl, and triceps extension (9). Exercises were presented to all subjects in the same sequence. Each of the exercises required subjects to begin in a standing position with feet approximately shoulder width apart, and each exercise was performed with a focus on accuracy and form. Squat and step exercises were performed to a 90° bend in the knee (monitored subjectively via the instructor). All alternating and unilateral exercises were performed for the desired number of repetitions on each side of the body. Subjects were given 90 seconds of rest between each set and between each exercise, and water-breaks were provided after the 3rd and 7th exercises.

Progression: Throughout the 6-week exercise program, subjects were progressed through intensity according to changes in RPE. This was achieved by recording RPE after each set of exercise throughout the duration of the exercise program, and when RPE dropped below 11 for a specific exercise the weight used was increased to match an RPE of 12 or 13. Volume of exercise was also progressed incrementally. At the beginning of the study, each subject performed the first 5 exercises for 2 sets of 5-8 repetitions. From that point on, the volume (exercises, sets, and repetitions performed) were increased for each exercise biweekly. Specifically, at week 3 subjects were asked to perform exercises 1-6 for 3 sets of 7 repetitions; at week 5 this increased to 4 sets of 7 repetitions for exercises 1-7, and finally at week 6 subjects performed 4 sets of 9-10 repetitions of all 9 exercises. The main goal of this progression schedule was to safely and slowly introduce a group of previously sedentary subjects to whole body resistance exercise. Lastly, subjects were asked to maintain their normal physical activity level outside of the supervised training program, however, non-supervised physical activity data were not recorded.

Statistical Analysis

Paired samples T-tests were used to compare all body composition and BMR data between baseline and 6 weeks. The average resistance load of the first exercise (front loaded squat) and training volume (total Kg moved during each session; calculated as resistance load * sets * repetitions * exercises) were also compared between baseline and 6 weeks with a paired-samples t-test. The front squat exercise was selected as an indicator of resistance load progression because it was performed throughout the entire program and is a full-body multi-joint exercise. Finally, a Pearson's correlation coefficient (r) was reported for any significant changes in any of the body composition variables (total mass [Kg], FM, FFM, %BF, BMI) and changes in absolute or relative BMR.

RESULTS

Of the 20 subjects who were initially recruited for participation, 19 completed the entire protocol (retention rate of 95%). Average BMR significantly increased from baseline (832.67Kcal*day^{-1} ± 310.13 [95% CI lower bound= 683.18, upper bound= 982.15]) to post-training (1079.43Kcal*day^{-1} ± 163.47 [95% CI lower bound= 1000.64, upper bound= 1158.23], t=4.64, p<.001) (Fig 1); and that difference remained after BMR was normalized to body mass (11.55Kcal*Kg^{-1}*day^{-1} ± 3.92 at pre [95% CI lower bound= 9.67, upper bound= 13.45] and 15.08 Kcal*Kg^{-1}*day^{-1} ± 2.80 at post [95% CI lower bound= 13.72, upper bound= 16.43]). There were no significant differences in FFM (t=-0.72, p=.478), FM (t=1.25, p=.227; Fig 2), BMI (t=1.89, p=.074), or %BF (t=-0.07, p=.941). However, there was a very small, but statistically significant increase in Total mass (72.36Kg ± 12.61 at pre [95% CI lower bound= 66.28, upper bound= 78.44] and 72.99Kg ± 12.56 at post [95% CI lower bound= 66.93, upper bound= 79.05], t=3.16, p=.005; Fig 2). There were no significant correlations between the change in Total mass and changes in absolute (r= -0.076, p=0.75) or relative (r= -0.119, p=0.628) BMR.

The average training volume significantly increased from 0 to 6 weeks (1229.15Kg ± 469.12 at pre [95% CI lower bound= 1003.05, upper bound= 1455.26]and 3122.63Kg ± 651.35 at post [95% CI lower bound= 2808.68, upper bound= 3436.57], t=11.487, p<.001) (Fig 3), as did the average resistance load of the front squat exercise (4.30Kg ± 1.19 at pre [95% CI lower bound= 3.73, upper bound= 4.87]and 8.13Kg ±1.38 at post [95% CI lower bound= 8.02, upper bound= 8.79], t=9.135, p<.001) (Fig 3). All subjects were able to achieve the desired sets and reps during each phase of progression.

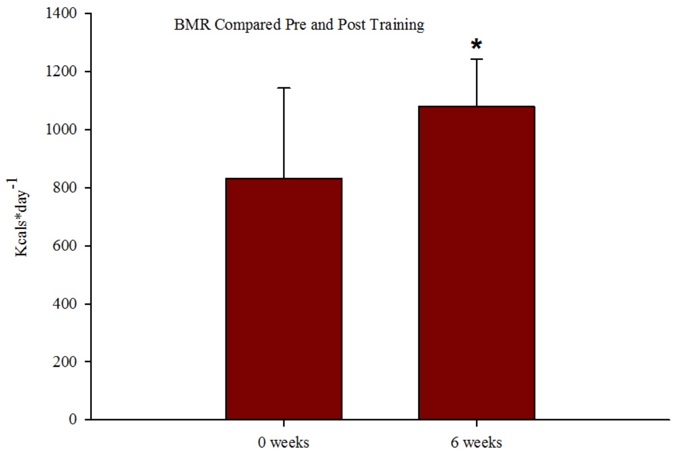

Figure 1. BMR compared between baseline (0 weeks) and post-training (6 weeks). * indicates a significant difference between time points ($p \leq 0.05$).

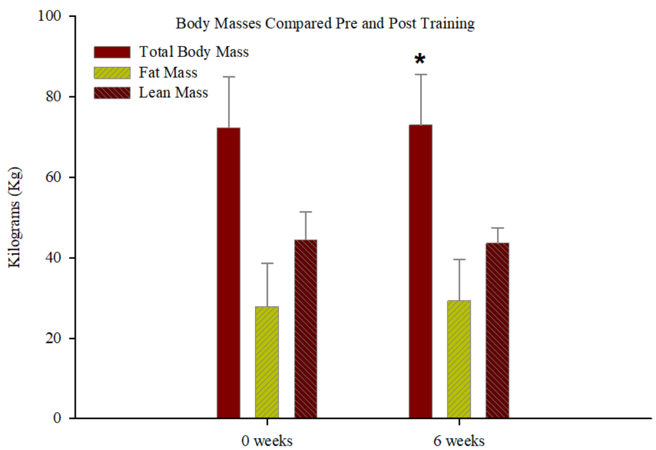

Figure 2. Total mass, FM, and FFM compared between baseline (0 weeks) and post-training (6 weeks). * indicates a significant difference between time points ($p \leq 0.05$).

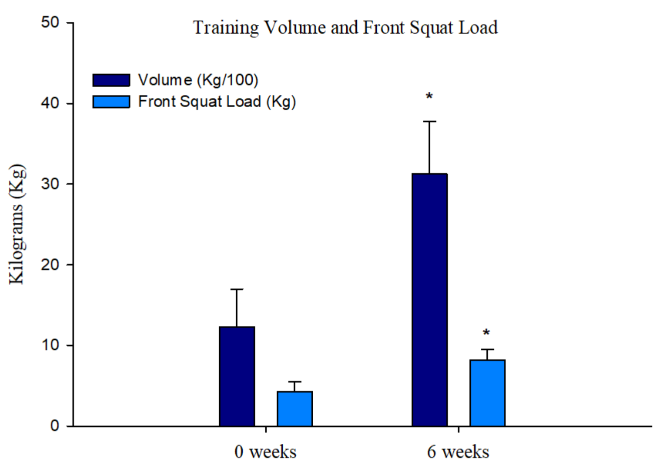

Figure 3. Training volume compared between baseline (0 weeks) and post-training (6 weeks). * indicates a statistically significant difference between time points ($p \leq 0.05$).

DISCUSSION

Results from this study suggest that 6 weeks of progressive intensity functional resistance exercise can elicit increases in BMR in this population, absent any significant changes in FFM, body fat, BMI, or FM. These results agree with those of previously published studies reporting a positive influence of resistance training on BMR (7-9). These results address a lack of research that examines the efficacy of a functional (non-traditional) and progressive exercise program designed specifically for inexperienced exercisers in a free-living condition. The purpose of the present study was to evaluate the effect of such a program on the BMR and body composition of a group of previously sedentary adult women. Previous research has used resistance exercise as a method for eliciting chronic increases in BMR (9, 26). However, most of these studies combine traditional exercise methods with strict dietary regulations to achieve these benefits, and such programs may have limited accessibility and adherence in the general population.

The ability to increase BMR may have implications for weight loss or weight maintenance; which improves the risk profiles for metabolic syndrome, type II diabetes, and cardiovascular disease. This study, like others, notes a disparity in the exercise-related changes in FFM and BMR. It is important to note that total mass did increase following exercise training; though the difference was not correlated with the changes observed in BMR. This suggests that resistance training may be a method by which BMR can be promoted without significant changes in FFM, FM, BMI, or body fat. This theory has been both supported (8) and disputed (5, 12) by other research. This evidence also supports the use of functional resistance exercise to help reverse the age-related declines in BMR (25), which could also help preserve bone mineral density (16).

Results from this study and others indicate that changes in FFM and total mass are not the sole mechanisms influencing changes in BMR. Therefore, researchers have attempted to identify the other potential factors that could influence an adaptation in BMR. One possible mechanism is an increase in oxidative capacity and fat oxidation in response to exercise training. Wang, Hikida, Staron and Simoneau (30) found that 18 weeks of high repetition resistance training significantly increased oxidative capacity, fat oxidation, and increased absolute mitochondrial density. The authors also reported a transition of fast-twitch (Type IIB/X) fibers to fast oxidative glycolytic (Type IIA) fibers. These modifications in muscle fiber structure are different from those reported with high intensity, low repetition resistance exercise; which is preferential to Type IIB/X fiber recruitment. The exercise program used in the present study was similar to the one used by Wang, Hikida, Staron and Simoneau (31), in that it targeted the intermediary Type IIA muscle fibers. Another proposed mechanism for the non-FFM related changes in BMR is altered thyroid function, specifically increased circulation of thyrotropin, triiodothyronine, and thyroxine (31). However, a series of experiments between 1988 and 1993 dispute this theory after researchers observed little to no change in the circulation of these hormones after periods of prolonged exercise training (2, 23, 24). Therefore, the exact mechanisms for non-FFM adaptations of BMR to exercise training remain somewhat elusive.

The limitations of this project are centered around the desire to maintain as much external validity as possible. For that reason, we did not collect dietary records. Therefore, we cannot exclude the possibility that subjects modified their dietary intake over the training period, which could influence BMR. However, there were only modest increases in total mass, with no statistically significant changes in FFM, FM, body fat, or BMI, suggesting that any possible increase in caloric consumption was not enough to elicit significant physiological changes. We also did not control for stage of menopause, which could also influence variation between subjects. Regarding the training program itself, we did not prescribe intensity based on a traditional 1 repetition maximal (1RM) strength assessment. Instead, we used a more subjective measure of intensity in RPE. While this reduced the control exerted on the exercise program, and likely resulted in lower exercise intensities, it made the program more applicable to a population of novice-exercisers. Finally, we did not record or report 1RM's as a measure of strength gain over the exercise program. Instead, we reported the increases in weight used during the front-loaded squat exercise, because it is a multi-joint exercise and is one of the few exercises that were performed for the entire 6 weeks. Therefore, any inferences in strength gains as a result of the resistance training program should be considered conservative estimates of actual strength gains.

In conclusion, the results from this study support the use of functional resistance training as a method for increasing BMR in a group of previously sedentary adult women. However, results from this study do not suggest that this exercise program was sufficient for eliciting weight loss. Furthermore, the authors make no assumptions on the mechanisms responsible for this relationship, but instead defer to future research on the link between resistance training adaptations and BMR independent of mass. Ultimately, this method of resistance training is an achievable (as indicated by a very high retention rate) and effective method for promoting basal energy metabolism in apparently healthy adult women.

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