PHYSIOLOGICAL CHANGES IN WOMEN FOLLOWING A CONCURRENT OR RESISTANCE TRAINING PROGRAM

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

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In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Department: Health, Nutrition, and Exercise Sciences

May 2012

Fargo, North Dakota

Graduate School

Title

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RESISTANCE TRAINING PROGRAM

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MASTER OF SCIENCE

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ABSTRACT

This research evaluated physiologic changes in women after a 12 week resistance training (RT) or concurrent training (CT) program. Eighteen women (38-61 years) were randomized to a training group that trained three times per week. Resistance workouts (both groups) included 30 minutes of exercises. The concurrent group also completed 30 min of moderate intensity cardiovascular exercise during each training session. Two-factor (group x time) repeated measures analysis of variance evaluated group differences and time-related changes in FFM and RMR. Alpha was set at $< .05$ for all analyses. Repeated measures ANOVA evaluated group differences and time-related changes in all other variables. Significant increases in FFM ($p = .045$), RMR ($p = .01$), bench press ($p = .0001$), and HDL ($p = .03$) were found for the entire sample from pre- to post-test. Neither training modality (RT or CT) proved superior in eliciting physiologic change in individuals.

ACKNOWLEDGMENTS

Many people have provided encouragement and assistance in the development and completion of this thesis, and I would like to take this opportunity to personally acknowledge and thank them. First, I wish to acknowledge my advisor Dr. Donna Terbizan for this thesis would not have been possible without her immense dedication. Over the past seven years she has mentored me, given me incredible opportunities and I appreciate her trust in my ability to contribute to her research interests. Through Dr. Terbizan’s mentoring, I have gained skills invaluable to my future research and writing efforts. I’ve been continually impressed by her kindness, writing expertise, and willingness to give so generously of her time. I can only hope in my future studies I can find another professor with as much caring, knowledge, and commitment as Doc T.

I would like to sincerely thank John Schuna for his help and patience in assisting me with my data analysis and results. Without his incredible ability with statistics I would surely still be attempting to make sense of it all.

I would like also like to express my sincere appreciation to the members of my committee who were extremely patient, helpful, and supportive throughout this process. I have learned much from the knowledge and guidance you have provided, thank you.

DEDICATION

This thesis is dedicated to my mother. You have taught me the importance of learning and instilled in me the desire to further my education. You have always been there for me and I could not ask for a better role model. You are my inspiration and have been an incredible support through this process and my life. I can only hope that someday I will be as great of an educator and mentor as you are. There are no words to express my gratitude and appreciation for your unconditional support. I can never thank you enough.

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LIST OF ABBREVIATIONS

CVD - cardiovascular disease

FFM - fat free mass

RMR - resting metabolic rate

EEPA - exercise expenditure from physical activity

HDL – high-density lipoprotein

LDL – low-density lipoprotein

PA - physical activity

PAEE – physical activity energy expenditure

BMI - body mass index

VO2 max - cardiovascular fitness

BP - blood pressure

HTN - hypertension

FM - fat mass

TEE - total energy expenditure

RT - resistance training

CT - concurrent training

PAR-Q - physical activity readiness questionnaire

3RM - three repetition max

1RM - one repetition max

BPM - beats per minute

VO2 - volume oxygen

VCO2 - volume carbon dioxide

CHAPTER I. INTRODUCTION

In the United States, cardiovascular disease (CVD) is the leading cause of death for both men and women among all races and ethnic groups. According to 2007 mortality rate data, more than 2200 Americans die each day with one death occurring every 39 seconds (Rogers et al., 2011). Cardiovascular risk profiling attempts to establish the presence of a number of risk factors that together with overweight and obesity, contribute to the progression of CVD (Schjerve et al., 2008). Risk factors for this disease that can be modified by a change in lifestyle include hypertension, obesity, insulin sensitivity, dyslipidemia, physical inactivity, and smoking. Gender, genetic factors, and advancing age also play a role; however, these factors cannot be controlled. Other related factors include metabolic syndrome, which is defined as a cluster of cardiovascular risk factors, and type 2 diabetes which has been known to be associated with marked increase in risk of CVD by up to 2 fold in men and 4 fold in women (Conroy et al., 2003). Risk factors for metabolic syndrome that can be modified by a change in lifestyle include hypertension, obesity, insulin sensitivity, dyslipidemia, physical inactivity, and smoking.

Obesity and physical inactivity contribute significantly to the development of multiple risk factors in the American population (Grundy et al., 1998). Experimental research has shown substantial evidence to support an association between physical fitness and its effect on these modifiable risk factors. However, most of the research linking physical activity and CVD has evaluated aerobic activity, and evidence is lacking focus in the area of resistance exercise and a combination of these exercise activities on CVD risk (Thompson et al., 2003). Despite the information gathered, there is also a lack of evidence of combined exercise and its effects on total risk for CVD and metabolic syndrome, specifically in the area of long term cohort data (Thompson et al., 2003).

In general, exercise decreases cardiovascular risk, but an optimal training program has yet to be identified (Schjerve et al., 2008). It is well established that obesity directly increases cardiometabolic risk and is also closely associated with development and progression of CVD (Schjerve et al., 2008). Obesity and physical inactivity appear to be associated with low aerobic capacity and impaired endothelial function, both serving as strong independent risk factors of mortality from CVD and other metabolic diseases (Grundy et al., 1998). Adverse changes in abdominal obesity, dyslipidemia, glucose tolerance, hypertension, and insulin resistance, become increasingly common with aging. Additionally, insulin resistance has been shown to be a major factor in development of metabolic syndrome and type 2 diabetes, which are both important risk factors for CVD (Sillanpaa et al., 2009). Aerobic exercise has been shown to reduce cardiovascular risk by reducing blood pressure, improving insulin sensitivity, and improving blood lipid profiles. These adaptations are also, in part, mediated by reduction in body fat induced by exercise (Ballor & Poehlman, 1992). Significant reduction in cardiac risk occurs with even moderate weight loss and improvements in body composition (Meka et al., 2008). Resistance exercise has also been shown to produce these adaptations, including reductions in body fat, therefore, also being beneficial in reducing CVD risk. Individuals who participate in physical activity have been shown to have a higher resting metabolic rate (RMR) and a lower percent body fat than do sedentary individuals (Ballor & Poehlman, 1992). Due to the different mechanisms that produce these changes, combined endurance and strength training may have synergistic benefits compared to either method alone.

Most of the research involving metabolic risk factors involves aerobic training, and does not directly evaluate the addition of resistance training (Thompson et al., 2003). Little is known about how prolonged strength and endurance training influences metabolic health, particularly in women (Sillanpaa et al., 2009). The evaluation of concurrent training is important to examine when investigating reduction of risk factors. With obesity recently being added as a primary risk for CVD, it is imperative to look closer into the potential benefits of concurrent training as it has been shown to improve body composition by decreasing adipose tissue and increasing fat free mass (FFM) (Meka, Kataragadda, Cherian, & Arora, 2008). Considering that resting metabolic rate (RMR) and exercise energy expenditure from physical activity (EEPA) account for approximately 90% of total energy expenditure, interventions that can increase these two components are potentially beneficial to decreasing and preventing increases in adiposity (Lemmer et al., 2001). This evidence suggests that both aerobic and resistance exercise contribute to a reduction in cardiovascular risk through reduction in metabolic risk factors and increased RMR (Ballor & Poehlman, 1992).

Investigations examining the effects of a concurrent strength and endurance training program on the RMR of both men and women are unexplored. Studies that have examined the effects on strength training and endurance training separately have produced inconsistent results (Lemmer et al., 2001). Additionally, there are no studies to date that have investigated the differences in the response of resting metabolic rate to concurrent training in females. The purpose of this study is to examine metabolic risk factor and RMR changes resulting from a resistance or concurrent training program in women.

Statement of the Problem

There is a lack of research concerning physiological changes comparing concurrent resistance and aerobic training and resistance training alone. Additionally, results are inconclusive as to whether concurrent and resistance training shows changes in RMR specifically among women.

Purpose of Study

The purpose of this study was to examine metabolic risk factor and RMR changes resulting from a resistance or concurrent training program in women.

Research Questions

Does concurrent and resistance exercise result in a change in RMR?

Are changes in RMR independent of changes in FFM?

Are three hours of physical activity per week adequate to result in significant changes in body composition and other physiological changes?

Limitations

Generalizability – this research was conducted involving is a primarily Caucasian sample recruited from staff and faculty at North Dakota State University making it difficult to generalize to other age, ethnic, and socioeconomic groups.

Seasonal and behavioral confounding factors – fall to winter in this region generally results in a change of daily activity levels due to the climate change.

Nutritional factors – there was an inability to control dietary behaviors of subjects. Additionally, there are changes in eating habits that also result from a change in season.

Small Sample Size – more than 18 subjects would generate greater statistical power

Previous Training History – those with previous training may see different changes than those without. Additionally sedentary individuals will see differences compared with those who are active

We were unable to completely control that workouts on all 3 days are performed as directed and include a full 30 minutes of resistance training and 30 minutes of cardiovascular exercise. While encouraged to make-up missed workouts, extended sickness, vacations, and conference attendance resulted in the inability for all participants to complete all workouts. Additionally, only two workouts were supervised leaving the third workout to the participant to complete on their own.

Definition of Terms

Target-heart rate zone – an event that will initiate and sustain a heart rate that is 60%-90% of an individual's maximum heart rate or 75-%-85% of a person's max VO2, or heart rate reserve, for a duration of time lasting between 20 and 60 minutes (American College of Sports Medicine [ACSM], 2000).

Resting Metabolic Rate (RMR) – Sum of the metabolic processes of the active cell mass required to maintain normal regulatory balance and body function at rest (McArdle, Katch, &, Katch, 2007).

Body Composition – refers to the relative percentage of body weight that is fat and fat-free tissue (American College of Sports Medicine [ACSM], 2000).

Concurrent Training – cardiovascular and resistance training within the same exercise session or within a few hours of one another (Leveritt, M., Abernethy, P., Barry, B., & Logan, P. 1999).

Maximal oxygen uptake (VO_{2max}) – is accepted as the criterion measure of cardiorespiratory fitness and is related to the functional capacity of the heart (American College of Sports Medicine [ACSM], 2000).

Bioimpedance analysis - an electrical method of assessing human body composition by measuring total body water and estimating fat free mass and fat mass (Rubiano, F. Nuñez, C., Heymsfield, S. 1999).

Three repetition maximum (3RM) – the heaviest weight that can be lifted three times using good form and is used to test maximal strength (American College of Sports Medicine [ACSM], 2000).

Body mass index (BMI) – used to assess weight relative to height and is calculated by dividing body weight in kilograms by height in meters squared (kg/m^2) (American College of Sports Medicine [ACSM], 2000).

Heart rate max (HR max) – predicted using (220-age) and used to determine intensity of exercise for an individual (American College of Sports Medicine [ACSM], 2000).

Repetition – once complete movement of a particular exercise (American College of Sports Medicine [ACSM], 2009).

Fat Free Mass (FFM)- represents the body mass devoid of all extractable fat. (McArdle, Katch, &, Katch, 2007).

Hypertension – Abnormal high blood pressure with diastolic >140 Hg/mm or systolic >90 Hg/mm (McArdle, Katch, &, Katch, 2007)

CHAPTER II. LITERATURE REVIEW

The purpose of this study was to examine metabolic risk factor and resting metabolic rate (RMR) changes resulting from concurrent training in women. During the past 50 years, prospective and experimental studies on physical activity have consistently demonstrated a reduced incidence of cardiovascular disease (CVD) events in the most physically active subjects. Data in the evidence has identified a causal relationship between physical activity and reduced risk factors for CVD. The results are strong with most active subjects generally showing CVD rates of half compared to the sedentary group. Additionally, it appears there is a graded inverse relationship between levels of activity and CVD rates. The following epidemiological studies as well as those concerning biological plausibility provide conclusive evidence that physical activity reduces the incidence of CVD (Thompson et al., 2003).

There is compelling evidence to suggest that physical activity, particularly improving cardiovascular fitness and muscular strength, should be encouraged to manage and reduce risk for CVD (Gaesser, 2007). Physical activity both prevents and helps treat many cardiovascular risk factors including obesity, high-density lipoprotein (HDL) concentrations, triglyceride concentrations, glucose intolerance, and elevated blood pressure. In combination with weight loss, exercise has been shown to decrease low-density lipoprotein (LDL) concentrations more than simply diet alone. Most of the research involving metabolic risk factors involves aerobic training, and does not directly evaluate the addition of resistance training (Thompson et al., 2003). Little is known about how prolonged strength and endurance training influences metabolic health, particularly in women (Sillanpaa et al., 2009). The evaluation of concurrent training is important to examine when investigating reduction of risk factors. With obesity recently being added as a risk for CVD it is imperative to look closer into the benefits of concurrent training as it has been shown to improve body composition by decreasing adipose tissue and increasing fat-free mass (FFM) (Meka et al., 2008). Experimental research has shown substantial evidence to support an association between physical fitness and its effect on these modifiable risk factors. In general, exercise decreases cardiovascular risk, but an optimal training program has yet to be identified (Schjerve et al., 2008).

It is well established that obesity directly increases cardiometabolic risk and is also closely associated with development and progression of CVD (Schjerve et al., 2008). Adverse changes in abdominal obesity, dyslipidemia, glucose tolerance, hypertension, and insulin resistance, become increasingly common with aging. Additionally, insulin resistance has been shown to be a major factor in development of metabolic syndrome and Type 2 Diabetes, which are both risk factors for cardiovascular disease (Sillanpaa et al., 2009). The metabolic effect of reduced muscle mass as a result of physical inactivity and normal aging contributes to the development of these risk factors. Significant reduction in cardiac risk occurs with even moderate weight loss and improvements in body composition (Meka et al., 2008). These adaptations are also, in part, mediated by reduction in body fat induced by exercise (Ballor & Poehlman, 1992). Resistance exercise has been shown to produce these beneficial metabolic adaptations, including reductions in body fat and may, therefore, also be beneficial in reducing CVD risk.

With obesity recently being added as a risk for CVD, it is imperative to look closer into the potential benefits of resistance training as it has been shown to improve body composition by decreasing adipose tissue and increasing fat free mass (FFM) (Meka et al., 2008). 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 exercise energy expenditure from physical activity account for approximately 90% of total energy expenditure, interventions that can increase these two components are potentially beneficial to decreasing and preventing increases in adiposity (Lemmer et al., 2001). This evidence suggests resistance exercise contributes to a reduction in cardiovascular risk through reduction in metabolic risk factors and increased RMR (Ballor & Poehlman, 1992).

Evidence relating FFM to RMR and total energy expenditure are sound, indicating a near perfect correlation. Individuals who participate in physical activity have been shown to have a higher RMR and a lower percent body fat than do sedentary individuals (Ballor & Poehlman, 1992). Cross sectional studies have shown that increased muscular strength is inversely associated with all cause and CVD mortality as well as development of metabolic syndrome. Epidemiological evidence further supports the use of increased resistance exercise for prevention of age related weight and fat gains. Despite these relationships, investigations examining the effects of a resistance training program on the RMR have produced inconsistent results (Lemmer et al., 2001). Studies that have examined the effects on strength training and endurance training separately have produced inconsistent results in regards to physiological change related to RMR. Additionally, those examining the effects of concurrent strength and endurance training and resistance only training on RMR, most specifically in women, remain largely unexplored (Poehlman et al. 1992).

Prediction and Prevention of CVD

Risk factor assessment and estimation of absolute CVD risk plays a vital role in prevention and should begin as early as age 20 (Meka et al., 2008). The SCORE project was initiated to develop a risk scoring system for use in clinical management of cardiovascular risk in European clinical practice. In order to establish a better estimation of risk methods, this project was done in three phases that were aimed at total cardiovascular risk rather than only risk of heart disease. The first phase involved developing simple risk charts for high and low risk populations; the development of methods for creating national risk charts; and, finally the integration of a computer based risk estimation application to be used in clinical settings. Datasets from 12 European cohort studies were assembled with a combined total of 205,178 participants. A Weibull two part model along with Cox regression models were used to develop a 10 year risk equation. Diabetes was not included in this study because of lack of data by the cohort studies, however, the equations and charts developed are still very much a useful tool for clinical prevention in Europe. Ten year risk charts were established for total cardiovascular risk based on the risk factors of age, blood pressure, cholesterol, and smoking (Conroy et al., 2003).

The impact of standard CVD risk factors on 10-year risk for development has been studied extensively and reliable prediction equations exist. The Framingham Study was the first to evaluate the impact of standard risk in a long-term follow-up (Grundy et al., 1998). In 1948, the study began with an original cohort of 5209 individuals and aimed to establish a correlation between CVD risk factors and risk estimation. In 1971, 5124 offspring and spouses of these original individuals were enrolled into the Framingham Offspring Study (Pencina et al., 2009). Data identified statistically significant risk factors to be used and those defined as “major” included: hypertension, high serum cholesterol, low high-density lipoprotein (HDL) levels, diabetes, and smoking. Advancing age is also included because of increased absolute risk associated with aging (Grundy et al., 1998). These data were used to develop the first 30 year risk estimate based on the theory that individuals may be more likely to adapt to necessary lifestyle changes on hearing that 30-year risk is much higher than previous 10 year risk models (Pencina et al., 2009),

The Framingham charts provide a realistic picture of a given individual's true and absolute relative risks. In addition to defining specific major risk factors, Framingham research reveals that both physical inactivity and obesity are positively associated with CVD and recognized by the American Heart Association as important risk factors. All of this information suggests that physical inactivity and obesity lead to development of most, if not all, of these risk factors.

Exercise Effects on Risk Factors

A number of cohort studies have demonstrated a consistent inverse association between physical fitness and incidence of Type 2 diabetes, CVD and metabolic syndrome. According to Gaesser (2007), "Exercise either alone or in combination of comprehensive lifestyle intervention is considered a cornerstone in the prevention and management of diabetes, CVD, and metabolic syndrome" (p.15). Ekelund et al. (2005) examined the association between physical activity (PA)and CVD over a five year period and was the first study to use valid objective measures to record Physical Activity Energy Expenditure (PAEE) and aerobic fitness. The study demonstrated benefits of increased physical activity by showing an inverse relationship between PAEE and metabolic syndrome, independent of obesity and aerobic fitness.

In the Aerobics Center Longitudinal Study (ACLS), individuals with low cardiorespiratory fitness had an average of 3.7 times higher risk of developing diabetes independent of body mass index (BMI). Additionally, overweight and obesity were associated with higher incidence of CVD mortality, but not after adjusting for fitness (Stofan, DiPietro, Davis, Kohl, & Blair, 1998). The correlation between risk factors and the occurrence of coronary events was also established in the Nurses' Health Study. A total of 84,129 women without previous CVD, cancer, or diabetes, were followed for 14 years. The lowest risk group included those who had a BMI < 25 did not smoke, and engaged in regular exercise. This group showed a relative risk of 0.17 (CI, 95% 0.07-0.41) for coronary events when compared to other women (Meka et al., 2008).

The addition of resistance exercise to aerobic activity has been shown to be increasingly beneficial, producing results of decreased body-fat mass, which has been proven to aid in weight maintenance and glycemic control. A number of exercise intervention studies have shown multiple health benefits seen with concurrent training, including improved glucose metabolism, lipid profile, blood pressure, immune function, and decreased chronic inflammation (Braith, & Stewart, 2006; Carroll, 2004; Woods, Vieira, & Keylock, 2006). In addition to physical activity, moderate to high levels of cardiorespiratory fitness and muscular strength appear to be protective against diabetes, CVD, and metabolic syndrome. Randomized studies ascertained the effect of strength training to enhance muscular strength, cardiovascular function, overall metabolic rate, and general quality of life (Ferketich et al., 1998; Schjerve et al., 2008; Sillanpaa et al., 2009; Wood et al., 2001).

Available data concerning physiological changes after periodized resistance training are limited. Additionally, inconsistency is shown concerning whether or not resistance training causes significant body composition changes. Physical training programs that have been shown to elicit whole body changes in lean and fat mass include both strength and aerobic training. A study by Bradley et al. (2000) showed that women who train with concurrent exercise five days a week effectively in decreased total body adiposity and increased lean tissue mass by 5.4%. In the same year, a study by LeMura et al. (2000) examined various modes of training and the effects on blood lipid profiles, cardiovascular fitness, and body composition after 16 weeks. The study compared aerobic and resistance training separately to concurrent training. Results showed a decrease in body fat by 10% and an increase in FFM of 3% in the concurrent training group. These results were similar to that of the resistance only group that reduced body fat by 11% and increased FFM by 4%. The concurrent training group also had similar strength gains as the resistance only group, indicating only small amounts of interference by the addition of aerobic training. While the aerobic group showed beneficial changes in blood lipid profile with increases in HDL and decreases in LDL and triglycerides, these changes were not seen in the concurrent or resistance only group. Additionally, the aerobic group increased maximal oxygen consumption (VO_2 max) while the concurrent training group had no increase in this area.

Randomized controlled trials that have used aerobic and resistance exercise have produced limited beneficial results mainly in the elderly and middle-aged people (Pistavos et al., 2009). A study by Boardley et al. (2007) used aerobic walking and resistance training on elderly subjects for 16 weeks and reported no change in lipid profile in comparison to the control group. Similar results were found by LeMura et al. (2007) who combined jogging and resistance training in young women for 16 weeks. A study by Lee et al. (1990) and Lee (2005) combined folk dance and resistance training in 85 middle aged adults for 24 weeks and showed similar results as previous studies. After 21 weeks of concurrent training, a study by Sillanpaa et al. (2009) on middle aged women showed significant increases in lean body mass, cardiovascular fitness, and strength. There were minor, however, not significant changes on resting blood pressure, cholesterol, and glucose concentration after training (Sillanpaa et al., 2009).

According to Wilson et al. (1998), weight loss as a non-pharmacological solution is perhaps the most effective measure in reducing blood pressure (BP). At least 44 randomized controlled trials including 2674 participants have studied the effect of exercise training on resting blood pressure showing an average reduction of systolic and diastolic blood pressure of 3.4 and 2.4 mm Hg respectively. When examining BP in a group of older men and women, significant training responses were found after 6 months of concurrent exercise. Systolic and diastolic BP was decreased and correlated with increases in cardiovascular fitness, FFM, reduced general and abdominal obesity, and increased strength. Higher levels of physical fitness have been shown to be associated with reduced hypertension (HTN) in men, however, exercise effects on BP in women and African Americans remains inconclusive (Pescatello et al., 2004). Additionally, studies have found no relationship between training frequency, time, or intensity suggesting that the dose-response curve for blood pressure is flat (Thompson et al., 2003)

Several studies, however, have shown strong associations between resistance training and hypercholesterolemia even after controlling for numerous confounding factors. A study by Kang et al. (2009) noted greater increases in lipolysis, fat utilization, and total energy expenditure when aerobic activity followed resistance training. This study also found that these benefits were linearly correlated with intensity. A significant decrease in LDL-cholesterol was found by both Park et al. (2003) and Kodama et al. (2007) in relation to a physically inactive group after 12-24 weeks of concurrent training. The ATTICA study by Pistavos et al. (2009), randomly enrolled 1514 healthy men and 1528 healthy women and then stratified them into groups classified as inactive, sufficiently active, highly active, only aerobic exercise, and highly active with a combination of aerobic and resistance exercise. Blood samples were taken from all participants and analysis revealed that aerobic in combination with resistance exercise had the most positive influence on various blood lipids (Pitsavos et al., 2009). Perhaps the largest and most carefully controlled study was the Health, Risk Factors, Exercise Training, and Genetics (HERITAGE) study, which included participants engaged in five months of exercise training. Results showed an average increase in HDL levels of 4.6% and a reduction in triglyceride and LDL concentrations of 3.7% and 5%, respectively (Thompson et al., 2003).

Concurrent Interaction

Strength and endurance training represent two opposite forms of training and elicit very different adaptive responses. Due to this difference in training, it is hypothesized that concurrent training may compromise optimal gains if either endurance or strength training was done separately. Research investigating the neuromuscular and performance adaptations associated with concurrent strength and endurance training has produced inconsistent results. Some studies have shown concurrent training to inhibit strength and power development without affecting development of aerobic fitness (Leveritt, Abernethy, Barry, & Logan, 1999). Other results show concurrent training to compromise the cardiovascular fitness benefits seen from endurance training alone while having no inhibitory effects on the development of strength. Endurance training in some studies has been associated with a loss of strength and in others shown strength gains. The outcome ultimately is dependent on the intensity, volume, and frequency of the specific training program, as well as past exercise and fitness level. A study by Sale, MacDougall, Jacobs, and Garner (1990) used a moderate concurrent training volume and compared it to strength training alone or endurance training alone. Results showed no interaction between the training groups. The concurrent training group made the same adaptations as the single training groups with no significant differences in gains in strength and VO_2 max. A study by Wood et al. (2000) examined concurrent training in 45 older adults and concluded that a combination of strength and cardiovascular training results in similar physiologic improvements as endurance or strength training alone, indicating no evidence of interference of cardiovascular exercise on strength gains. Data from a study by Ferketich, Kirby, and Alway et al. (1998) suggested strength training combined with endurance training induced greater muscular strength and submaximal endurance than endurance training alone. It was also noted in this study that resistance training did not compromise cardiovascular adaptations that occur with endurance training in the elderly. It appears from this data that concurrent training produces favorable muscular adaptations and fatigue resistance without loss of cardiovascular benefits and may be more beneficial than endurance training alone.

Contrary to these results, concurrent training has been shown to interfere with strength training, muscular strength, or muscle mass development during longer training periods (Hakkinen et al., 2003; Hickson, 1980; Kraemer et al., (1995); Sillanpaa et al., 2008). Interference is generally observed during high volume and high intensity training. Overtraining and opposing adaptations may be a cause for interference at the muscular level caused by concurrent strength and endurance training. Most of the studies investigating concurrent training have been performed in men with less data available in women (Sillanpaa et al., 2009)

Resting Metabolic Rate

Results of studies examining endurance training effect on RMR have been equivocal. Most research focused on exercise and RMR has been on the short-term effects of physical exercise on metabolic rate rather than on the potential effect of long term effects of training on RMR (Sjodin et al., 1996). The results of some investigations have shown increases in RMR while others have shown it to be unaltered or decreased. Many factors are shown to influence metabolic rate with the largest being FFM. Therefore, interventions increasing lean body mass, such as those containing resistance training, are proposed to increase RMR (Geliebter et al., 1990). Considering endurance exercise produces minimal gains in FFM when compared to resistance exercise it would seem that individuals who participated in endurance activities would have a lower FFM and ultimately a lower RMR (Dolezal & Potteiger, 1998).

It is unclear as to when the effect on 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 for someone participating in a program to see these training effects of increased RMR at rest. A study by Sjodin et al. (1996) found that athletes had a 13% higher RMR than controls, and increased to 16% when related to both FFM and fat mass (FM). The majority of cross sectional studies have shown an approximate 5-20% higher RMR in trained subjects compared to sedentary controls (Sjodin et al., 1996). However, a study by Poehlman et al. (2002) studied resistance and aerobic trained young women and found that energy expenditure of exercise training are primarily derived from the direct energy cost of exercise and not from chronic elevation of RMR.

Many factors are shown to influence metabolic rate with the largest being FFM. Therefore, interventions increasing FFM, such as those containing resistance training, are proposed to increase RMR (Geliebter et al., 1990). Considering endurance exercise produces minimal gains in FFM when compared to resistance exercise it would seem that individuals who participated in endurance activities would have a lower FFM and ultimately a lower RMR (Dolezal & Potteiger, 1998). Contrary to this understanding are results of a study by Ballor and Peohlman (1992) that examined the differences between resistance training and aerobic training on RMR in women. Results from this study showed that both aerobic and resistance trained women had less total percent body fat and subcutaneous body fat than did sedentary women. Regular exercise of both types was associated with higher RMR compared with the sedentary group. When adjusted for FFM the aerobic group had a significantly higher RMR than did that of the resistance and sedentary groups. They also found that the amount of body fat was positively correlated with total cholesterol, fasting triglycerides, and insulin concentrations (Ballor & Poehlman, 1992).

The results of RMR differences between groups support a similar study by Poehlman et al. (1992) that found both the aerobic and resistance training groups to have higher RMR than the sedentary group, with the aerobic group being the highest (Poehlman et al., 1992). These results are also inconsistent with the well-understood evidence that resistance training increases FFM, the biggest component in RMR. These studies suggest that the mechanisms by which aerobic and resistance training increase RMR are different, making it sensible to include both in a concurrent training program when looking to maximize the benefits and increasing RMR (Ballor & Poehlman, 1992).

With advancing age comes reduction in muscle mass resulting in declines in RMR and total energy expenditure (TEE) at an average of 1-2% per decade. Several studies have examined resistance (RT) programs in regards to advancing age in efforts to maintain RMR, strength, and fend off increases in body fat (Byrne & Willmore, 2001; Campbell, Crim, Young, & Evans 1994; Hunter, Wetzstein, Fields, Brown, & Bamman, 2000; Pratley et al. 1994; Lemmer et al., 2001; Ryan, Pratley, Elahi, & Goldberg 1995; Taffe, Pruittt, Reim, Butterfield, & Marcus, 1995). A study by Hunter et al. (2000) examined RT, RMR, and 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. (1994) also assessed the changes in a similar population resulting from a 12 week progressive RT program. Results showed RMR increased by 6.8%. However, when expressed relative to increases in FFM, the increase was not significant. Conclusions suggest RT results in a significant and substantial increase in energy requirements in older men and women. These results are consistent with those found by Prately et al. (1994) following a 16 week RT program where results showed increases in strength, FFM, and RMR increased by an average of 7.7%. In this study, changes in RMR and FFM were not as closely correlated as those previously mentioned. At baseline RMR correlated with FFM, however, a disproportionate increase was seen and changes in RMR did not correlate with those seen in FFM (Campbell et al., 1994).

Contrary to these results, Taffe et al. (1995) 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 reevaluated. During this time period, strength increased further, however, again no change was seen in RMR for either group (Taffe et al., 1995).

Similar results were found for women in a study by Lemmer et al. (2001) that examined age and gender differences in response to RT and changes in RMR and energy expenditure of physical activity (EEPA). Forty participants underwent a 24 week RT program and were divided into four groups dependent on age and gender. All groups showed a significant increase in FFM with no variation by gender, but there was a greater increase in FFM in younger subjects. When pooled together, RMR showed an absolute increase of 7% with no variation depending on age. When groups were split by gender, there were significant differences found in RMR but not in FFM increases. Both men and women showed similar increases in FFM, however, neither young nor older women showed significant increases in absolute or relative RMR in response to the training program. In contrast, men showed an increase of 9% in RMR. When corrected for FFM, there was still a significant increase in RMR in response to the RT program for all groups. This finding is consistent with results by Prately et al. (1994) and Campbell et al. (1994) indicating there are other mechanisms responsible for increased RMR other than FFM. The results of this study showed for the first time that changes in RMR in response to RT is affected by gender but not by age (Lemmer et al. 2001)

A study by Ryan et al. (1995) studied the RMR changes of postmenopausal women with resistance training with weight loss (RTWL) or just resistance training (RT) before and after a 16-week resistance training session. Results showed that the RT attenuated loss of FFM in the RTWL group and there was no change in RMR despite an average 5kg loss in weight. These results are consistent with a similar study by Campbell et al. (1994) where increases in FFM produced an increase in RMR. Both of these studies concluded that RT may be more beneficial than aerobic exercise to maintain and increase FFM and RMR (Ryan et al., 1995). Another study examining training and RMR was conducted by Byrne and Wilmore (2001) and examined RMR changes in women during RT and a combination of RT and walking (RTW). There were significant increases in FFM in both groups as a result of the training program. Interestingly, even though both groups increased FFM, the RT group showed a significant increase in RMR while the RTW group showed a significant decrease (Byrne & Willmore, 2001).

Conclusion

Combined endurance and strength training may be more effective in improving physical fitness, body composition, and metabolic health than either method alone (Sillanpaa et al., 2009). Findings of several cross-sectional studies (Sigal et al., 2007; Geliebter et al., 1997; Sillanpaa et al., 2009) have concluded that aerobic and resistance training each improved glycemic control, however the combination of these two forms of exercise is superior to either type of exercise alone. Studies (Alberga & Kenny, 2010; Braith & Stewart, 2006) have also shown that muscular strength is inversely associated with all-cause mortality and the prevalence of metabolic syndrome independent of cardiorespiratory fitness levels.

There is compelling evidence to suggest that physical activity, particularly exercise to improve cardiorespiratory fitness and muscular strength have positive effects on all modifiable risk factors and appear to be protective against diabetes, CVD, and metabolic syndrome (Gaesser, 2007). The Framingham and SCORE studies played a vital role in defining the contribution of risk factors to CVD and provide a realistic picture of a given individual’s absolute relative risk. Exercise intervention studies have demonstrated health benefits of both aerobic and resistance exercise including improved glucose metabolism, lipid profile, blood pressure, immune function and a decrease in chronic inflammation. Associations seen in activity studies measuring specific intensity levels are stronger than those relying on objective measures such as self-reporting. One large limitation of these studies is their lack of generalizability due to underrepresented ethnic groups. Most of the current research including the Framingham study has been conducted on a sample of entirely Caucasian participants (Grundy et al., 1998).

Research regarding changes in RMR following a training program has shown inconsistent results. While evidence suggesting RT increases FFM and subsequently RMR, results of some studies in women shows no correlation. Other studies show significant increases in RMR to only be attributed to FFM, while others still show increases after FFM is controlled. Additional research is warranted specifically in women with regards to resistance, aerobic, and combined training and their effect on FFM and RMR. The extent to which increased FFM has on RMR changes remains unknown. Furthermore, research to determine which and to what extent additional physiological factors result in RMR increases independent of FFM.

Additional physiological and basic research is needed to provide further scientific rationale supporting the importance of physical activity. Specifically, new research should examine the mechanisms by which exercise reduces CVD risk as well as other chronic conditions where exercise may produce positive effects. It is important to develop information on the optimal amount of exercise and physical activity to produce beneficial outcomes and to understand individual differences. The contribution of physical inactivity to the development of our country and the world's obesity epidemic also warrants further investigation. Despite all of the research correlating obesity and inactivity to development of multiple CVD risk factors and the positive effects of exercise on specific risk factors, there remains a significant lack of evidence utilizing exercise as a form of prevention, treatment, and risk reduction. The important point here is that the research is not beneficial if it is not effectively applied. Using evidence of the benefits of exercise on all associated modifiable risk factors we can assume that a prescription for an exercise program involving both resistance followed by aerobic exercise will decrease defined risk scores for development of CVD.

CHAPTER III. MATERIALS AND METHODS

The purpose of this study was to examine metabolic risk factor and RMR changes resulting from concurrent or resistance training. Participants consisted of 18 women aged 36-61 years recruited through an email listserv message to the staff and faculty of North Dakota State University in Fargo, ND. The recruitment email explained the goals of the research, the population we were seeking, and provided a date for an informational seminar that was held to entertain any questions. Individuals were recruited to participate in two experimental groups. Please see Appendix A for the email script used. Independent variables include resistance and aerobic exercise. Dependent variables measured consisted of blood pressure, blood lipids, resting metabolic rate, body composition, weight, waist circumference, and muscular strength.

This study was approved by the NDSU Institutional Review Board. At the seminar interested participants were informed of risks and benefits both verbally and in writing. An informed consent and Physical Activity Questionnaire (PAR-Q) was 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 strength and endurance training and testing, a previous cardiac event, or were unable to receive physician consent if required. All relevant medications were recorded. Participants taking medications were not excluded unless it interfered with their ability to participate.

Exercise attendance was recorded and missed workouts were made up during the following weeks so everyone finished with the same amount of workout volume. Initial testing began in the second week in September. All pretest and posttest variables were assessed in the same manner and conducted by the same individuals. Due to the short length of the program, midpoint testing did not take place. Posttest procedures took place the third week of December and following analysis all information was shared with participants after returning in January.

Participants were given precise instructions regarding the fitness tests prior to coming to the testing facility and were asked not to engage in physical activity beyond their basic daily activities 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.

Measures and Procedures

This battery of assessments was taken prior to intervention and was then repeated after 12 weeks of training. All anthropometric measures were conducted by the same individual. Height, weight, arm, thigh, and waist circumferences were conducted with participants wearing light clothing. After lying supine for five minutes, systolic and diastolic blood pressure (BP) was measured using an automated machine (GE Dinamp Carescape v100, Waukesha WI) that has been validated as an accurate measure of BP (Beaubien, Card, Card, Biem, & Wilson, 2002). Height was measured by a free standing stadiometer, and weight by a calibrated electric scale (Detecto® DR600). Waist and limb circumferences were measured using a non-elastic tape measure. Waist was measured halfway between the lower rib and iliac crest of the hip. Midpoint of each right and left upper arms and thighs were also measured (Welborn & Dhaliwal, 2007).

Body composition was measured using a Lange skinfold caliper at designated sites. Subjects were measured at the triceps, suprailiac, and thigh. The Jackson Pollack three site equation was used to calculate body composition. Body composition as determined from skinfold measurement has been shown to correlate well with hydrostatically determined body density and to be both reliable and valid (Jackson & Pollock, 1984). Participants were asked to go to a local clinic to have their blood drawn. Fasting serum glucose, total cholesterol, triacylglycerol, low-density lipoprotein cholesterol, and high-density lipoprotein cholesterol concentrations were measured by Sanford Health Laboratory, Fargo, ND, and analyzed by an automated chemistry analyzer.

Resting metabolic rate (RMR) was measured through the use of a Medical Graphics® metabolic cart and BreezeSuite 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 asked to come in the morning after having fasted for a minimum of 10 hours to have their RMR measured. Following the subject arrival they 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 machine (GE Dinamp Carescape v100, Waukesha WI) that has been validated as an accurate measure of BP (Beaubien, Card, Card, Biem, & Wilson, 2002). Once rested for 30 minutes, RMR was measured using a Medgraphics® metabolic cart in the following manner: a nose clip was placed on the nose and a mouth piece used to measure air (gas) exchange, analyzing the expired gases for volume, the amount of oxygen extracted by the lungs, and the amount of carbon dioxide produced and expelled to the atmosphere. The RMR test lasted 20 minutes. The BreezeSuite software uses VO2 and VCO2 from each breath to calculate RMR using the abbreviated Weir equation [(3.94 VO2) + (1.106 VCO2)] * 1.44 (Weir, 1949).

Fitness testing took place in the afternoon for aerobic and strength measurements. A three repetition-maximum (3RM) protocol to measure upper and lower body strength was chosen again due to the age and fitness level of participants. The 3RM method has been shown to be accurate [$r^2 = .81$] by Wood, Maddalozzo, and Harter (2002) and reliable with a correlation of $r > .9$ and a high interclass correlation coefficient $r > .99$ by Levinger et al. (2009) estimating 1RM strength. Participants were instructed on the tests and given a light treadmill warm-up. When assessing 3RM, a warm-up set was given followed by gradually increased resistance until the participant could no longer complete three repetitions. A timed two minutes rest was given between attempts. Upper body strength was tested first using a barbell bench press on a flat bench. The same 3RM procedures were used to test lower body strength using a hip sled. Post testing took place in the same matter as pre testing with at least 72 hours between the last training session and RMR testing.

Following strength testing, cardiovascular endurance was examined using a 1-mile Rockport walking test. This walk test was used to estimate fitness level and maximal oxygen uptake (Kline, Porcari, Hintermeister, Freesdon, & Ward, 1987). Participants were asked to walk one mile as quickly as possible without running. Time to complete the mile was be recorded in addition to final heart rate (BPM) using a Polar® heart rate monitor. This method was chosen over other tests due to the age and fitness level of the participants. Additionally, walking was the primary form of aerobic exercise in the program.

Training

Following pretesting, participants were randomized into a resistance training only (RT) or concurrent training (CT) groups. The CT group completed 30 minutes of resistance training followed immediately by 30 minutes of aerobic training. The RT group performed the same resistance training protocol as the CT group without the aerobic training. Participants were asked to exercise in accordance with protocol three days per week with two days assisted and supervised by professionals at NDSU. The third day was performed by the participants at an exercise facility of their choice throughout the local area. Exercise plans were monitored and progressed appropriately. Attendance was verified through direct observation and written exercise records.

The resistance program began with eight machine and free weight exercises for the main muscle groups. Resistance began at an intensity level of reaching failure between 8-12 repetitions for each set progressing from two sets the first and second weeks to three sets the third week. In the fourth week, load was increased maintaining a repetition range of 8-12 continuing with three sets. Intensity and exercises were monitored and progressed based on individual development. As the individuals progressed, free weight and more advanced exercises were added to the program.

Immediately following completion of the resistance training, heart rate monitored exercise was performed by the CT group. Age estimated (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 begin at 60-75% HR max. In the third week, intensity was assessed and increased to 75-90% HR max.

CHAPTER IV. ARTICLE I. PHYSIOLOGIC CHANGE IN WOMEN FOLLOWING A RESISTANCE OR CONCURRENT TRAINING PROGRAM

Abstract

Evidence is well established concerning the positive effects of exercise on risk factors for chronic disease. Large epidemiological studies have consistently shown reduced mortality rates and reduced risk for disease in those individuals with higher cardiovascular fitness. Resistance training has also been shown to have positive effects on reducing specific risk factors for disease. However, which exercise program has the most significant effect on reducing risk has yet to be determined. **Purpose:** The purpose of this study was to evaluate physiologic changes in women after a 12 week resistance training (RT) or concurrent (CT) program. **Methods:** Eighteen women aged 36-61 years were randomized to a RT or CT group, with training occurring three times per week. Both groups participated in resistance workouts that included 30 minutes of upper and lower body exercises where fatigue occurred between 8-12 repetitions. The CT group then participated in 30 min of moderate intensity cardiovascular exercise during each training session. Pretesting and post-testing included: height; weight; resting blood pressure; body composition from skinfolds; arm, thigh, and waist circumference measurements; strength in bench press and leg press using a 3-Repetition Maximum (3RM) measurement; and cardiovascular fitness using a Rockport walk test. Fasting serum glucose, total cholesterol, triacylglycerol, low-density lipoprotein cholesterol, and high-density lipoprotein cholesterol concentrations were measured by Sanford Health Laboratory, Fargo, ND, and analyzed by an automated chemistry analyzer. RMR data was collected in a fasted state, following 30 minutes of rest, for a minimum of 20 minutes. FFM was calculated by subtracting fat mass from total body mass, where fat mass was derived by multiplying total body mass by percent body fat measured via the Jackson-Pollock skinfold technique. Two-factor (group x time) repeated measures analysis of variance (ANOVA) was used to evaluate group differences and time-related changes in FFM and RMR. The relationship between FFM and RMR change scores was evaluated using a Pearson correlation. A repeated measures MANOVA was used to evaluate group differences and time-related changes in all other variables. Alpha was set < 0.05 for all analyses. **Results:** Several (2 x 2) repeated measures ANOVAs were used to compare dependent variable scores across time and between treatment groups. No statistically significant differences between treatments or time by treatment interactions were found for any of the measured variables. Improvements in upper body strength, body composition, FFM, HDL cholesterol, LDL cholesterol, blood pressure, and cardiovascular fitness were observed among the entire sample; however, only increases in HDL cholesterol and bench press strength were significant ($p = 0.03$ and $p < 0.001$, respectively). **Conclusions:** Results indicate that upper body strength and HDL cholesterol significantly increased among women in this sample after 12 weeks in a RT or CT exercise program, however, no significant difference was found between groups. No other variables were found to significantly change. Neither training modality (RT or CT) proved superior in eliciting significant physiologic change or risk factor reduction in individuals.

Introduction

During the past 50 years, prospective and experimental studies on physical activity have consistently demonstrated a reduced incidence of cardiovascular disease (CVD) events in the most physically active subjects. Data in the evidence has identified a causal relationship between physical activity and reduced risk factors for CVD. Research indicates that most active subjects have half the CVD rates compared to a sedentary group. Additionally, it appears there is a graded inverse relationship between levels of activity and CVD rates (Thompson et al., 2003).

In general, exercise decreases cardiovascular risk, but an optimal training program has yet to be identified (Schjerve et al., 2008). It is well established that obesity directly increases cardiometabolic risk and is also closely associated with development and progression of CVD (Schjerve et al., 2008). Obesity and physical inactivity appear to be associated with low aerobic capacity and impaired endothelial function, serving as strong independent risk factors of mortality from CVD and other metabolic diseases (Grundy et al., 1998). Adverse changes in abdominal obesity, dyslipidemia, glucose tolerance, hypertension, and insulin resistance become increasingly common with an increase in age. Additionally, insulin resistance has been shown to be a major factor in development of metabolic syndrome and type 2 diabetes, which are both risk factors for cardiovascular disease (Sillanpaa et al., 2009). The metabolic effect of reduced muscle mass as a result of physical inactivity and normal aging contributes to the development of these risk factors. Significant reduction in cardiac risk occurs with even moderate weight loss and improvements in body composition (Meka et al., 2008). These adaptations are also, in part, mediated by reduction in body fat induced by exercise (Ballor & Poehlman, 1992).

There is compelling evidence to suggest that physical activity, particularly improving cardiovascular fitness and muscular strength, should be encouraged to manage and reduce risk for CVD (Gaesser, 2007). Physical activity both prevents and helps treat many cardiovascular risk factors including obesity, high-density lipoprotein (HDL) concentrations, triglyceride concentrations, glucose intolerance, and elevated blood pressure. In combination with weight loss, exercise has been shown to decrease low-density lipoprotein (LDL) concentrations more than simply diet alone (Thompson et al., 2003). Due to the different mechanisms that produce these changes, combined endurance and strength training may have synergistic benefits compared to either method alone. Little is known about how prolonged strength and endurance training influences metabolic health, particularly in women (Sillanpaa et al., 2009). The evaluation of combined cardiovascular and resistance training (concurrent) is important to examine when investigating reduction of risk factors. With obesity recently being added as a risk for CVD, it is imperative to look closer into the potential benefits of concurrent training (CT) as it has been shown to improve body composition by decreasing adipose tissue and increasing fat free mass (FFM) (Meka et al., 2008).

The purpose of this study was to evaluate physiological changes of cardiovascular disease risk factors in women following a CT or RT program. Specifically, change in strength, body composition, VO2, blood pressure, total cholesterol, and HDL were evaluated.

Methods

Participants

Participants were 18 women aged 36-61years 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. An 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 strength and endurance training and testing, a previous cardiac event, or were unable to receive physician consent if required. All relevant medications were recorded.

Study Design

After signing informed consent forms and receiving physician's consent if needed, participants completed the following 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 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 or intervention (CT) group. The intervention group engaged in CT consisting of 12 weeks of progressive aerobic and RT three days a week totaling 60 minutes per session. The control group participated in the same RT 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 the 12 weeks of training.

Experimental Procedures

Session 1: anthropometric testing. All anthropometric measures were conducted by the same individual. Height, weight, waist, arm, and thigh circumferences were conducted with participants wearing light clothing. After lying supine for five minutes, systolic and diastolic blood pressure (BP) was measured using an automated machine (GE Dinamp Carescape v100, Waukesha WI) that has been validated as an accurate measure of BP (Beaubien, Card, Card, Biem, & Wilson, 2002). Height was measured by a free standing stadiometer, and weight by a calibrated electric scale (Detecto® DR450, Daugherty Webb City, MO). Circumference measurements were conducted using a non-elastic tape measure. Waist was measured halfway between the lower rib and iliac crest of the hip. The midpoint of each right and left upper arms and thighs were also measured (Welborn & Dhaliwal, 2007).

Body composition was measured using a Lange skinfold caliper at designated sites. Females were measured at the triceps, suprailiac, and thigh. Jackson-Pollock three site equations were used to calculate body composition. Body composition as determined from skinfold measurement has been shown to correlate well with hydrostatically determined body density and to be both reliable and valid (Jackson & Pollock, 1984). Participants were asked to go to a local clinic to have their blood drawn. Fasting serum glucose, total cholesterol, triacylglycerol, LDL, and HDL concentrations were measured by Sanford Health Laboratory, Fargo, ND, and analyzed by an automated chemistry analyzer.

Session 2: 3RM strength and aerobic testing. A three repetition-maximum (3RM) protocol to measure upper and lower body strength was chosen due to the age and fitness level of participants. The 3RM method has been shown to be valid and reliable at estimating 1RM strength (Wood, Maddalozzo, & Harter, 2002). Participants performed a 5-minute light treadmill warm-up and were instructed on the 3RM strength assessments. Upper body strength was tested with a barbell bench press. The same procedures were used to test lower body strength using a hip-sled. When assessing 3RM, a warm-up set was given followed by gradually increased resistance until the participant could no longer complete three repetitions. A timed two minutes rest was given between attempts.

Following strength testing, cardiovascular endurance was examined using a 1-mile Rockport walking test. This walk test was used to estimate fitness level and maximal oxygen uptake (Kline, Porcari, Hintermeister, Freesdon, & Ward, 1987). Participants were asked to walk one mile as quickly as possible without running. Time to complete the mile was recorded in addition to final heart rate (BPM) using a Polar® heart rate monitor. This method was chosen over other tests due to the age and fitness level of the participants. Additionally, walking was the primary form of aerobic exercise in the program.

Treatment Groups

Concurrent training (CT). This group completed both RT and aerobic training. The resistance program was completed first and began with eight machine and free weight exercises for the main muscle groups. Volume began at 12 repetitions for each set for each exercise and progressed from two sets during the first and second weeks to three sets the third week. In the fourth week, load was increased maintaining a failure repetition range of 8-12 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.

Immediately following completion of the RT, heart rate monitored exercise was performed 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.

Control. This group completed the same RT exercise program described for the CT group but did not complete the cardiovascular training.

Results

Subject demographics are presented in Table 1. Subjects groups were not significantly different pre to post. Several (2 x 2) repeated measures ANOVAs were used to compare dependent variable scores across time and between treatment groups and represented in Table 2. No statistically significant differences between treatments or time by treatment interactions were found for any of the measured variables. Improvements in upper body strength, body composition, FFM, HDL cholesterol, LDL cholesterol, blood pressure, and cardiovascular fitness were observed among the entire sample; however, only increases in HDL cholesterol and bench press strength were significant ($p = .03$ and $p < .001$, respectively).

Table 1. Demographics

	RT Group (n=8)				**CT Group (n=10)**			
	Pre		Post		Pre		Post	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	52.13	7.26			48.82	7.08		
Height (inches)	65.81	2.24			65.64	2.92		
Weight (lbs)	175.03	31.40	174.39	32.36	161.37	36.33	162.66	35.68
Body Fat (%)	31.97	8.32	29.93	6.40	27.37	9.02	26.15	7.55

Table 2. Repeated Measures 2x2 ANOVA

Factors	CT Group (n=10)				RT Group (n=8)				Combined Groups (n=18)			
	Pre		Post		Pre		Post		Pre		Post	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Bench Press (lbs)	73.5	5.5	84.0	5.6	61.3	6.1	71.9	6.3	68.1	4.2	78.6	4.3*
Leg Press (lbs)	231.0	21.6	255.0	18.9	237.5	24.2	255.0	21.1	233.9	15.7	241.9	14.2
HDL (mg/Dl)	59.9	3.4	64.1	4.3	61.0	3.8	65.9	4.8	60.4	2.5	64.9	13.3*
LDL (mg/Dl)	87.5	11	88.5	13.7	112.2	12.3	112.0	15.3	98.0	8.5	98.9	10.3
Systolic BP (mm/Hg)	112.6	3.3	112.2	3.5	121.8	3.7	121.6	3.9	116.7	2.6	116.4	2.9
Diastolic BP (mm/Hg)	67.0	2.3	64.9	2.4	71.5	2.6	68.4	2.7	69.0	1.8	66.4	1.8
VO_2 max (ml/kg/min)	31.7	2.2	33.7	2.1	27.2	2.4	27.5	2.4	101.6	2.3	30.9	1.7
FFM (lbs)	110.6	4.1	113.7	4.9	117.4	4.5	121.0	5.5	114.0	3.1	117.3	3.7*

Significantly different than before training. * $p < 0.05$

Discussion

The addition of resistance exercise to aerobic activity has been shown to be increasingly beneficial, producing results of decreased body-fat mass, which has been proven to aid in weight maintenance and glycemic control. A number of exercise intervention studies have shown multiple health benefits seen with CT, including improved glucose metabolism, lipid profile, blood pressure, immune function, and decreased chronic inflammation (Braith, & Stewart, 2006; Carroll, 2004; Woods, Vieira, & Keylock, 2006). In addition to physical activity, moderate to high levels of cardiorespiratory fitness and muscular strength appear to be protective against diabetes, CVD, and metabolic syndrome. This evidence supports the American College of Sports Medicine's Position Stand on Exercise and Physical Activity for Older Adults (Chodzko-Zajko et al., 2009). Randomized studies ascertained the effect of strength training to enhance muscular strength, cardiovascular function, overall metabolic rate, and general quality of life (Ferketich et al., 1998; Schjerve et al., 2008; Sillanpaa et al., 2009; Wood et al., 2001).

This study did not demonstrate significant change in cardiovascular disease risk factors after strength or CT programming other than an increase in HDL when groups were combined. A number of cohort studies, however, have demonstrated a consistent inverse association between physical fitness and incidence of type 2 diabetes, CVD and metabolic syndrome. Given a longer study length as in the following studies, perhaps change would have been more significant as this intervention lasted only 12 weeks. Ekelund et al. (2005) examined the association between PA and CVD over a five year period and was the first study to use valid objective measures to record Physical Activity Energy Expenditure (PAEE) and aerobic fitness. The study demonstrated benefits of increased physical activity by showing an inverse relationship between PAEE and metabolic syndrome, independent of obesity and aerobic fitness. In the Aerobics Center Longitudinal Study (ACLS), individuals with low cardiorespiratory fitness had an average 3.7 times higher risk of developing diabetes independent of BMI. Additionally, overweight and obesity were associated with a higher incidence of CVD mortality, but not after adjusting for fitness (Stofan, DiPietro, Davis, Kohl, & Blair, 1998). The correlation between risk factors and the occurrence of coronary events was also established in the Nurses' Health Study. A total of 84,129 women without previous CVD, cancer, or diabetes, were followed for 14 years. The lowest risk group included those who had a BMI < 25 did not smoke, and engaged in regular exercise. This group showed a relative risk of 0.17 (CI, 95% 0.07-0.41) for coronary events when compared to other women (Meka et al., 2008).

Available data concerning physiological changes after periodized RT in women are limited. Additionally, inconsistency is shown concerning whether or not RT causes significant body composition changes. Physical training programs that have been shown to elicit whole body changes in lean and fat mass include both strength and aerobic training. However, other studies show that strength and endurance training can be antagonistic when combined (McCarthy, Agre, Graff, Myron, Pozniak, & Vailas, 1995). One important distinction of this study is that no negative interaction was seen by the addition of endurance training to a resistance program. Both groups increased FFM with no difference between groups. Additionally, the CT group was not significantly different from the RT group in any of the tested variables following the intervention.

A study by Bradley et al. (2000) showed that women who trained with CT exercise five days a week effectively decreased total body adiposity and increased lean tissue mass by 5.4%.

Subjects in our study significantly increased FFM and decreased body fat, however, not significantly. A study in the same year by LeMura et al. (2000) examined various modes of training and the effects on blood lipid profiles, cardiovascular fitness, and body composition after 16 weeks. The study compared aerobic and RT separately to CT. Results showed a decrease in body fat by 10% and an increase in FFM of 3% in the CT group. While the aerobic group showed beneficial changes in blood lipid profile with increases in HDL and decreases in LDL and triglycerides, these changes were not seen in the CT or RT group. Additionally, the aerobic group increased VO_2 max while the CT group had no increase in this area. These results were similar to that of our study in the RT group reduced body fat by 11% and increased FFM by 4%. The CT group also had similar strength gains as the RT, indicating only small amounts of interference by the addition of aerobic training. Similar to the study by LeMura et al. (2000), significant positive changes were also seen in HDL, upper body strength, and FFM by our CT and RT groups.

Randomized controlled trials that have used aerobic and resistance exercise have produced limited beneficial results mainly in the elderly and middle-aged people (Pistavos et al., 2009). A study by Boardley et al. (2007) used aerobic walking and RT with elderly subjects for 16 weeks and reported no change in lipid profile in comparison to the control group. Similar results were found by LeMura et al. (2007) who combined jogging and RT in young women for 16 weeks. After 21 weeks of CT, a study by Sillanpaa et al. (2009) in middle aged women showed significant increases in lean body mass, cardiovascular fitness, and strength. Similar to our study there were minor, however, not significant changes on resting blood pressure, cholesterol, and glucose concentration after training.

Conclusion

Significant increases were seen in HDL, FFM, and bench press strength across both groups. Decreases in body fat were also seen, however, not significant. No interference was seen with the addition of cardiovascular training to RT as there were no significant differences between groups. CT participants engaged in 90 minutes of cardiovascular and 90 minutes of resistance exercise/week. While participants met the 2-3 days/week ACSM guidelines for RT, current ACSM guidelines recommend ≥150 minutes of moderate intensity cardiovascular exercise per week to improve and maintain cardiovascular fitness. While CT participants engaged in a total of 180 minutes of activity, lack of significant changes seen in cardiovascular fitness could be attributed to being less than the guidelines. Additionally, it is unclear if 12 weeks is enough time to induce chronic physiologic change induced by RT. It appears additional minutes per week and a longer intervention time is needed to affect chronic disease risk parameters.

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CHAPTER V. ARTICLE II. RESTING METABOLIC RATE CHANGES IN WOMEN FOLLOWING DIFFERENT EXERCISE TRAINING PROGRAMS

Abstract

Research examining changes in resting metabolic rate (RMR) following an exercise training program has shown inconsistent results. While evidence suggests resistance training (RT) increases fat-free mass (FFM) and subsequently RMR, results of some studies have suggested that FFM increases in women may not elicit increases in RMR. Additional research in women is needed to explore the effects of RT, and combined resistance and aerobic training (CT) on FFM and RMR. **Purpose:** The purpose of this study was to evaluate FFM and RMR changes in women after a 12 week RT or CT program. **Methods:** Eighteen women aged 36-61 years were randomized to a RT or CT group, with training occurring three times per week. Both groups participated in resistance workouts that included 30 minutes of upper and lower body exercises where fatigue occurred between 8-12 repetitions. The CT group then participated in 30 minutes of moderate intensity cardiovascular exercise during each training session. Pre- and post-test RMR data was collected in a fasted state, following 30 minutes of rest, for a minimum of 20 minutes. FFM was calculated by subtracting fat mass from total body mass, where fat mass was derived by multiplying total body mass by percent body fat measured via the Jackson-Pollock skinfold technique. Two-factor (group x time) repeated measures analysis of variance (ANOVA) was used to evaluate group differences 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 $< .05$ for all analyses. **Results:** Significant increases (mean ± *SE*) in FFM (+1.5 ± .7 kg, $p = .045$) and RMR (+77.4 ± 26.1 kcal, $p = .01$) were found for the entire sample from pre-to post- test. No significant differences in FFM (RT = 54.1 ± 2.2 kg, CT = 50.9 ± 2.0 kg, $p = .30$) or RMR (RT = 1477.5 ± 73.1 kcal•day^{-1}, CT = 1427.9 ± 65.4 kcal•day^{-1}, $p = .62$) were found between the RT and CT groups. In addition, no significant group x time interactions were found for the FFM ($p = .85$) and RMR ($p = .41$) analyses. FFM and RMR change scores were highly correlated ($r = .68$, $p < .01$) **Conclusions:** 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.

Introduction

With obesity recently identified as a risk for CVD, it is imperative to look closer into the potential benefits of resistance training because it has been shown to improve body composition by decreasing adipose tissue and increasing fat free mass (FFM) (Meka, Kataragadda, Cherian, & Arora, 2008). 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 exercise energy expenditure from physical activity account for approximately 90% of total energy expenditure, interventions that can increase these two components are potentially beneficial to decreasing and preventing increases in adiposity (Lemmer et al., 2001). This evidence suggests that resistance exercise contributes to a reduction in cardiovascular risk through a reduction in metabolic risk factors and increased RMR (Ballor & Poehlman, 1992).

Evidence relating FFM to RMR and total energy expenditure are sound, indicating a near perfect correlation. Individuals who participate in physical activity have been shown to have a higher RMR and a lower percent body fat than do sedentary individuals (Ballor & Poehlman, 1992). Cross sectional studies have shown that increased muscular strength is inversely associated with all-cause and CVD mortality as well as development of metabolic syndrome. Epidemiological evidence further supports the use of increased resistance exercise for prevention of age related weight and fat gains. Despite these relationships, investigations examining the effects of a resistance training program on the RMR have produced inconsistent results (Lemmer et al., 2001). Studies that have examined the effects on strength training and endurance training separately have produced inconsistent results in regards to physiological change related to RMR. Additionally, those examining the effects of combined cardiovascular and resistance training (concurrent) strength and endurance training and resistance only training on RMR, most specifically in women, remain largely unexplored (Poehlman et al., 1992).

Results of studies examining the effect of endurance training on RMR have been equivocal. Most research focused on exercise and RMR has been on the short-term effects of physical exercise on RMR rather than on the potential effect of long term effects of training on RMR (Sjodin et al., 1996). The results of some investigations have shown increases in RMR (Hunter, Wetzstein, Fields, Brown, & Bamman, 2000; Campbell, Crim, Young, & Evans, 1994; Ryan, Pratley, Elahi, & Goldberg, 1995) while others have shown it to be unaltered or decreased (Byrne & Willmore, 2001; Ballor & Poehlman, 1992; Geliebter et al., 1997; Lemmer et al., 2001; Taffe, Pruitt, Reim, Butterfield, & Marcus, 1995). Although many factors are shown to influence RMR, FFM has been shown to be the largest influencing factor. Therefore, interventions increasing FFM, such as those containing resistance training, are proposed to increase RMR (Geliebter et al., 1990). Considering endurance exercise produces minimal gains in FFM when compared to resistance exercise it would seem that individuals who participated in just endurance activities would have a lower FFM and ultimately a lower RMR (Dolezal & Potteiger, 1998).

Research regarding changes in RMR following a training program has shown inconsistent results. 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 for someone participating in a program to see the training effects of increased RMR at rest. While evidence suggests RT increases FFM and subsequently RMR, results of some studies in women shows no correlation. Poehlman et al. (2002) suggests no chronic changes in RMR are seen and that increases are primarily derived from the direct cost of energy. Other studies show significant increases in RMR to only be attributed to FFM (Campbell, 1994; Hunter et al., 2000) while others still show increases after FFM is controlled (Ballor & Poehlman, 1992; Pratley et al., 1994; Ryan et al., 1995).

Because of previous inconsistent results, additional research is warranted specifically in women with regards to resistance, aerobic, and combined training and their effect on FFM and long term effects on RMR. The extent to which factors other than FFM have on RMR in women remain unknown. Furthermore, continuing research to also determine which and to what extent additional physiological factors result in RMR increases independent of FFM. The purpose of this study was to examine chronic resting metabolic rate (RMR) changes resulting from concurrent training in women.

Methods

Participants

Participants were 18 women aged 36-61 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. An 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 strength and endurance training and testing, a previous cardiac event, or are unable to receive physician consent if required. All relevant medications were recorded.

Study Design

After signing informed consent forms and receiving physician’s consent if needed, participants completed the following 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

Session 1: body composition testing. Body composition was measured using a Lange skinfold caliper at the triceps, suprailiac, and thigh. Jackson-Pollack three-site equation was used to calculate body composition. Body composition as determined from skinfold measurement has been shown to correlate well with hydrostatically determined body density and to be both reliable and valid (Jackson & Pollock, 1984). Weight was measured by a calibrated electric scale (Detecto® DR450, Daugherty Webb City, MO).

Session 2: resting metabolic rate testing. Resting metabolic rate (RMR) was measured through the use of a Medical Graphics® metabolic cart using BreezeSuite software. This measurement was done on a pre-post basis with a minimum of 72 hours from their last training or testing session. Participants were asked to come in the morning after having fasted for a minimum of 10 hours to have their RMR measured. Following the subject arrival they 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 machine (GE Dinamp Carescape v100, Waukesha WI) that has been validated as an accurate measure of BP (Beaubien, Card, Card, Biem, & Wilson, 2002). Once rested for 30 minutes, RMR was measured using a Medgraphics® metabolic cart in the following manner: a noseclip was placed on the nose and a mouth piece used to measure air (gas) exchange, analyzing the expired gases for volume, the amount of oxygen extracted by the lungs, and the amount of carbon dioxide produced and expelled to the atmosphere. The RMR test lasted 20 minutes. The BreezeSutie software uses volume oxygen (VO2) and volume carbon dioxide

(VCO_2) from each breath to calculate RMR using the abbreviated Weir equation [(3.94 VO_2) + (1.106 VCO_2)] * 1.44 (Weir, 1949).

Session 3: 3RM strength and aerobic testing. A three repetition-maximum (3RM) protocol to measure upper and lower body strength was chosen due to the age and fitness level of participants. The 3RM method has been shown to be accurate at estimating 1RM strength (Wood, Maddalozzo, & Harter, 2002). Participants performed a 5-minute light treadmill warm-up and were instructed on the 3RM strength assessments. Upper body strength was tested with a barbell bench press. The same 3RM procedures were used to test lower body strength using a hip-sled. When assessing 3RM, a warm-up set was given followed by gradually increased resistance until the participant could no longer complete three repetitions. A timed two minute rest was given between attempts. Following strength testing, cardiovascular endurance was estimated using a 1-mile Rockport walking test **(**Kline, Porcari, Hintermeister, Freedson, & Ward, 1987). This method was chosen over other tests due to the age and fitness level of the participants. Additionally, walking was the primary form of aerobic exercise in the program. Participants were asked to walk one mile as quickly as possible without running. Time to complete the mile was recorded as was the final heart rate (BPM) using a Polar® heart rate monitor.

Treatment Groups

Concurrent training (CT). This group completed both resistance training and aerobic training. The resistance program was completed first and began with eight machine and free weight exercises for the main muscle groups. Volume began at 12 repetitions for each set for each exercise and progressed from two sets the first and second weeks to three sets the third week. In the fourth week, 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.

Immediately following completion of the resistance training, heart rate monitored exercise was performed by the CT group. Age predicted (220-age) heart rate max (HR max) was used to determine the individuals 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.

Resistance training (RT). This group completed the same resistance training exercise program described for the concurrent group but did not complete the cardiovascular training.

Results

Table 3 presents subject demographics. Subjects groups were not significantly different pre to post. Two-factor (group x time) repeated measures analysis of variance (ANOVA) was used to evaluate group differences 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 $< .05$ for all analyses. Significant increases (mean ± *SE*) in FFM (+1.5 ± .7 kg, p = .045) and RMR (+77.4 ± 26.1 kcal, p = .01) were found for the entire sample from pre- to post- test. No significant differences in FFM (RT = 54.1 ± 2.2 kg, CT = 50.9 ± 2.0 kg, p = .30) or RMR (RT = 1477.5 ± 73.1 kcal•day^{-1}, CT = 1427.9 ± 65.4 kcal•day^{-1}, p = .62) were found between the RT and CT groups (Table 4). In addition, no significant group x time interactions were found for the

FFM ($p = .85$) and RMR ($p = .41$) analyses. FFM and RMR change scores were highly correlated ($r = .68$, $p < .01$) as seen in Table 5.

Table 3. Demographics

	RT Group (n=8)				**CT Group (n=10)**			
	Pre		Post		Pre		Post	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age	52.13	7.26			48.82	7.08		
Height (cm)	167.16	5.67			166.73	7.42		
Weight (kg)	79.56	14.27	79.27	17.70	73.35	16.51	73.94	16.22
Body Fat (%)	31.97	8.32	29.93	6.40	27.37	9.02	26.15	7.55

Table 4. RMR and FFM Group * Time

	CT Group (n=10)				RT Group (n=8)				Combined Groups (n=18)			
	Pre		Post		Pre		Post		Pre		Post	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
RMR(kcal/day)	1379.1	60.9	1476.7	73.9	1451.4	68.1	1503.6	82.6	1411.2	44.9	1488.7	53.5*
FFM(kg)	50.3	1.9	51.7	2.3	53.4	2.1	55.0	2.49	51.8	1.4	53.1	1.7*

Significantly different than before training. * $p < 0.05$

Table 5. Correlation

		FFM Change	RMRCh
FFM Change	Pearson Correlation	1	.681**
	Sig. (2-tailed)		.002
	N	18	18
RMRCh	Pearson Correlation	.681**	1
	Sig. (2-tailed)	.002	
	N	18	18

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 1. RMR Group * Time (kcal•day^{-1})

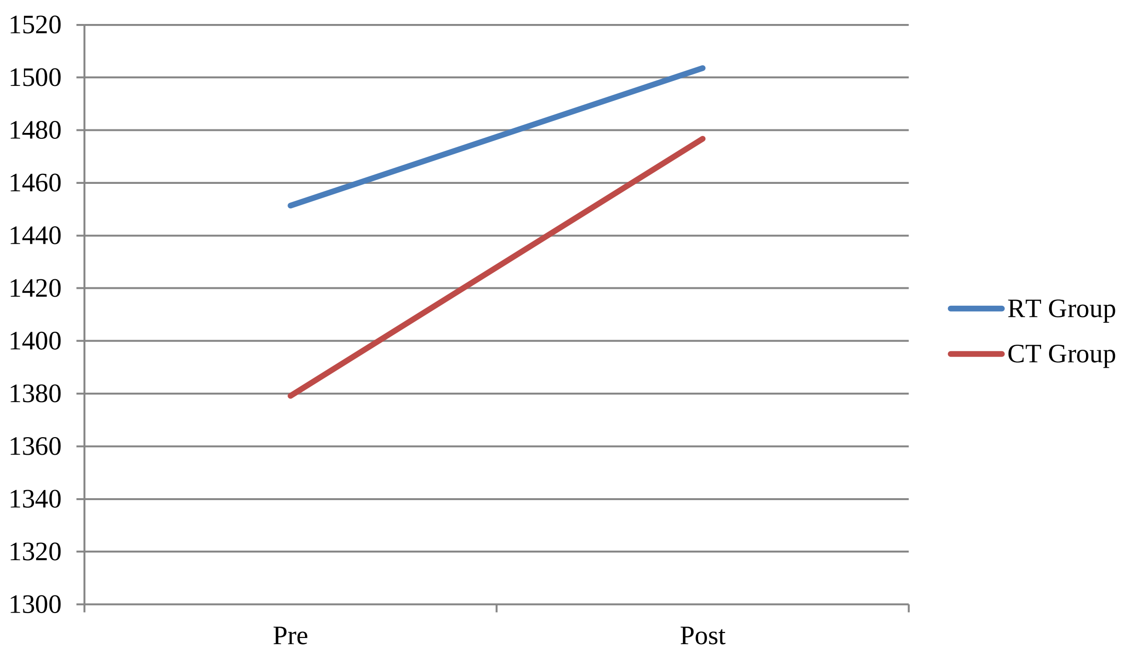
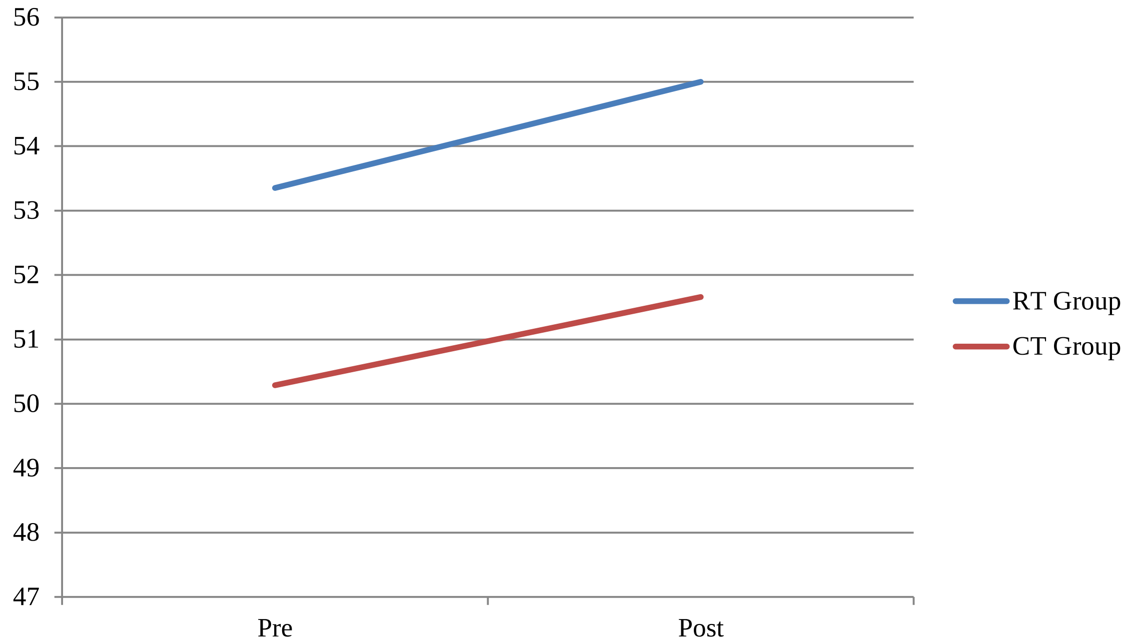


Figure 2. FFM Group * Time (kg)



Discussion

This study shows that resistance training and concurrent training result in a significant increase in RMR in women. While both groups completed the same resistance training program and both increased similarly in FFM, however, the mean increase of the CT RMR (+97.6 kcal) was nearly two times greater than the RT group (+52.25 kcal). The change of RMR between groups, however, was not shown to be statistically significant. These changes are illustrated in Figure 1 and 2. This lack of significance between groups is most likely to be attributed to lack of statistical power. If the trend continued and a larger sample was provided, the CT may have had a significantly larger increase than that of the RT group.

Studies including both men and women have shown similar results to those seen in our study of women. A study by Hunter et al. (2000) 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., (1994) 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. (1994) 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 (2001) examined RMR changes in women during RT and a combination of RT and walking (RTW). 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. (1995) 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. (1995) increases in FFM and RMR were seen.

Contrary to our results, several studies show no increase in RMR among women following a RT program. Taffe et al. (1995) 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. (2001) that examined age and gender differences in response to RT and changes in RMR and energy expenditure of physical activity (EEPA). 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. (2002) 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.

Insight on why the group that participated in aerobic training had a higher RMR may be similar to a study by Ballor and Poehlman (1992) 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. (1992) that found both the aerobic and resistance training groups to have higher RMR than the sedentary group with the aerobic being the highest. These results are inconsistent with the well-understood evidence that resistance training in creases FFM, the biggest component in RMR. These studies (Ballor & Poehlman, 1992; Poehlman et al., 1992) 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 into a concurrent program when looking to maximize the benefits and increasing RMR. Our study showed a correlation that 82% of RMR change was attributed to FFM change indicating 18% was attributed to other unknown physiologic factors.

Conclusions

Research regarding changes in RMR following a training program has shown inconsistent results. While evidence suggesting RT increases FFM and subsequently RMR, results of some studies in women shows no correlation. Other studies show significant increases in RMR to only be attributed to FFM, while others still show increases after FFM is controlled. Additional research is warranted specifically in women with regards to resistance, aerobic, and combined training and their effect on FFM and RMR. The extent to which increased FFM has on RMR changes remains unknown. Furthermore, research to determine which and to what extent additional physiological factors result in RMR increases independent of FFM.

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. Evidence is limited with only one other study 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.

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CHAPTER VI. SUMMARY

The purpose of this study was to examine physiologic changes in women after a resistance (RT) or concurrent training (CT) intervention as it relates to risk factors for chronic disease. We then dug further to investigate the changes in resting metabolic rate (RMR) following these two interventions. This was to evaluate if one intervention was superior to the other in eliciting favorable changes in body composition and RMR, which may also contribute to reduction of risk for chronic disease. Our investigation of risk factor variables found only significant increases over time in HDL and bench press, however, no significant difference between groups. While favorable changes were seen in risk factors by both groups, changes were not significant and neither group was found to be superior. Evaluation of RMR change indicated the CT had a greater, however not significant, increase in RMR than the RT group despite similar increases in FFM. Conclusions indicate mechanisms other than FFM cause increases in RMR.

Limitations of this study include generalizability as our sample was primarily middle-aged Caucasian individuals recruited from staff and faculty at North Dakota State University making it difficult to generalize to other age, ethnic, and socioeconomic groups. Considering this study took place in the fall semester seasonal and behavioral confounding factors could have been a factor limiting changes in weight and body composition. Fall to winter in this region generally results in a change of daily activity levels due to the climate change. Nutritional factors were not controlled in this study. Additionally, there are changes in eating habits that also result from a change in season. A small sample size of only 18 individuals limited statistical power. With a larger sample we would have more than likely seen more statistical change in variables tested. Finally, individuals with previous training may have seen less change than those who were previously sedentary. Some subjects in this study had participated in previous exercise intervention studies.

Future research should look to investigate the length of a program to elicit change in risk factors for disease. It is unclear if 12 weeks is enough time to induce chronic physiologic change induced by resistance training. Furthermore, it appears additional minutes per week and a longer intervention time is needed to affect chronic disease risk parameters. Previous research investigating RMR and FFM change in women from training programs are limited and results are equivocal. Additionally, investigation is warranted on what mechanisms are related to increases RMR other than increases in FFM.

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APPENDIX A. RECRUITMENT EMAIL

From: Donna Terbizan <D.Terbizan@ndsu.edu>

Date: Fri, 10 Sep 2010 10:49

To: "NDSU-FACULTY@LISTSERV.NODAK.EDU"

Subject: BISON ON THE MOVE - 2010

Interested in physical activity and improving your health? We are looking for NDSU staff or faculty members to participate in our research study starting in September 2010. The research we are conducting looks at the effect of physical activity (specifically resistance training and cardiovascular training) and nutrition education on risk factors of chronic disease. Training will occur on campus in the Human Performance Laboratory (HPL) in the Bentson Bunker Fieldhouse twice per week with you training one other day at a site of your choosing. Times for training in the HPL have yet to be determined, but may occur in early morning, noon, or late afternoon.

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of <u>any other reason</u> why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to <u>all</u> PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active -- begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant -- talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

<u>Informed Use of the PAR-Q</u>: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ______________________________

SIGNATURE ______________________________ DATE ______________________

SIGNATURE OF PARENT ______________________________ WITNESS ______________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

APPENDIX C. IRB APPROVAL

NDSU NORTH DAKOTA STATE UNIVERSITY

Institutional Review Board

Office of the Vice President for Research, Creative Activities and Technology Transfer
NDSU Dept. 4000
1735 NDSU Research Park Drive
Research 1, P.O. Box 6050
Fargo, ND 58108-6050

701.231.8995
Fax 701.231.8098

Federalwide Assurance #FWA00002439
Expires April 24, 2011

June 12, 2009

Dr. Donna Terbizan
Dept. of Health, Nutrition and Exercise Science

IRB Full Board Review of: **"The Effect of Physical Training and Nutrition Education on Risk Factors of Chronic Disease"**, Protocol **#HE09263**

Co-investigator(s) and research team: **Pamela Hansen, Ardith Brunt, Yeong Rhee, Bryan Christensen, Sherri Stastny, Candice Lee**

Research site(s): **NDSU** Funding: **n/a**

The protocol referenced above was reviewed at a convened meeting on June 12, 2009, and the IRB voted for: ☐ approval ☒ approval, contingent on minor modifications. These modifications have now been accepted. IRB approval is based on the original submission, with revised: consent form (received 6/12/09).

Approval expires: 6/11/2010 **Continuing Review Report Due: 5/1/2010**

Please note your responsibilities in this research:

- All changes to the protocol require approval from the IRB prior to implementation, unless the change is necessary to eliminate apparent immediate hazard to participants. Submit proposed changes using the *Protocol Amendment Request Form*.
- All research-related injuries, adverse events, or unanticipated problems involving risks to participants or others must be reported in writing to the IRB Office within 72 hours of knowledge of the occurrence. All significant new findings that may affect the risks to participation will be reported in writing to the subjects and IRB.
- If the project will continue beyond the expiration date, the IRB must review and approve a continuing review report prior to this date. The IRB Office will typically send a reminder letter approximately one month prior to the report due date; however, timely submission of the report is your responsibility. Should IRB approval of the project lapse, recruitment of subjects and data collection must cease.
- When the project is complete, submit a final report so that IRB records can be inactivated. Federal regulations require that IRB records on a protocol be retained for three years following project completion. Both the continuing review report and the final report should be submitted according to instructions on the *Continuing Review/Completion Report Form*.
- Research records may be subject to a random or directed audit at any time to verify compliance with IRB regulations.

Thank you for cooperating with NDSU IRB policies, and best wishes for a successful study.
Sincerely,

Kristy Shirley

Kristy Shirley, Research Compliance Administrator - IRB

Impact for Participants (future, current, or prior):

1. Will the change(s) alter information on previously approved versions of the recruitment materials, informed consent, or other documents, or require new documents?
   ☐ No
   ☒ Yes - attach revised/new document(s)

2. Could the change(s) affect the willingness of *currently* enrolled participants to continue in the research?
   ☒ No
   ☐ Yes - describe procedures that will be used to inform current participants, and re-consent, if necessary:

3. Will the change(s) have any impact to *previously* enrolled participants?
   ☒ No
   ☐ Yes - describe impact, and any procedures that will be taken to protect the rights and welfare of participants:

----------FOR IRB OFFICE USE ONLY--------

Request is: ☒ **Approved** ☐ **Not Approved**	
Review: ☐**Exempt, category#:** ____ ☒**Expedited** ~~**method, category #**~~ Review of minor change ☐**Convened meeting, date:** ____	
IRB Signature: Kristy Shirley	**Date:** 9/8/2010
Comments:	

Protocols previously declared exempt: (Allow 5 working days) If the proposed change does not alter the exemption status, the change may be administratively reviewed by qualified IRB staff, chair, or designee. If the change(s) would alter this status, Expedited or Full Board review will be required.

Protocols previously reviewed by the expedited method: (Allow 10 working days) Most changes may also be reviewed by the expedited method, unless the change would increase risks to more than minimal, and/or alter the eligibility of the project for expedited review.

Protocols previously reviewed by the full board: Minor changes (not involving more than minimal risks, or not significantly altering the research goals or design) may be reviewed by the expedited method (allow 10 working days). Those changes determined by the IRB to be more than minor will require review by the full board (due 10 working days prior to next scheduled meeting).