Physiological Adaptations to a Concurrent Sprint Interval and Resistance Training Program in Aging Women

by

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Abstract

PURPOSE: To investigate the physiological adaptations to a high intensity concurrent exercise training (CET) program composed of Sprint Interval Training (SIT) and Resistance Exercise Training (RET) in recreationally active women ages 40-64. A secondary purpose of this investigation was to determine whether the addition of vertical incline to SIT produces significant adaptive body composition and aerobic capacity responses than level grade SIT CET in this cohort. METHODS: Seventy-six healthy, recreationally active females (52.2 ±7.2 yrs; 2.1 L•min-1 Abs VO^2_{max}; 72.7 ± 15.3 kgs) volunteered for the 12 week CET study. Preliminary and post testing consisted of 1 repetition max (1 RM) back squat, 1 RM bench press, body composition assessment through Dual-energy X-ray Absorptiometry (iDEXA) and aerobic capacity measures including maximal oxygen consumption (VO_{2max}). Prior to the start of the intervention, participants were pair matched according to baseline VO_{2max} values and randomly assigned into either level grade (0%) SIT (CSIT0) CET or incline (6%) SIT (CSIT6) CET experimental groups. Participants attended 3 training sessions per week, each entailing of concurrent undulating periodization RET and SIT protocol consisting of 40 second sprints at speed and/or incline to incite 95% of each participant's age-predicted maximal heart rate (HR_{max}), performed in alternating order at the same time each day. RESULTS: Significant interactions for time were observed in body composition parameters including upper and lower body muscular strength (1 RM back squat and bench press, $P < 0.0001$), fat mass ($P = 0.002$) and visceral adipose tissue ($P = 0.048$). Aerobic capacity improvements were observed for time to

exhaustion during maximal test (T_{max}), speed required to achieve 95% of HR_{max} (V_{max}) and

VO_{2max} ($P < 0.0001$). No significant effects between groups were observed for any other

measures. CONCLUSION: These findings indicate that the combination of high intensity

interval and resistance training results in significant improvements in aerobic capacity, body

composition and muscular strength in aging women 40-64 years of age. This CET protocol

provides the proper stimulus for physiological adaptive responses which may prevent age and

physical inactivity-related declines; therefore supporting proper body composition, aerobic

capacity and functional ability in older adults.

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List of Abbreviations

ACSM	American College of Sports Medicine
AET	Aerobic Exercise Training
AP	Anterior-Posterior spine
a-v O_2	Arteriovenous Oxygen
BMD	Bone Mineral Density
CDC	Center for Disease Control and Prevention
CET	Concurrent Exercise Training
CV	Cardiovascular
CVD	Cardiovascular Disease
CT	Concurrent Training
iDEXA	Dual-emission X-ray Absorptiometry
FM	Fat Mass
FN	Femoral Neck
FFM	Fat Free Mass
FSH	Follicle Stimulating Hormone
GH	Growth Hormone
HIIT	High Intensity Interval Training
INC	Incline Running
LBM	Lean Body Mass

PA	Physical Activity
PCOS	Polycystic Ovarian Syndrome
Q	Cardiac Output
QOL	Quality of Life
RM	Rep Max
RMR	Resting Metabolic Rate
RET	Resistance Exercise Training
SIT	Sprint Interval Training
SV	Stroke Volume
V_{max} Running	Velocity Associated with VO_2max
VO_2	Volume of Oxygen Consumption
VO_2max	Maximal Oxygen Consumption
WHO	World Health Organization

CHAPTER I

INTRODUCTION

The pandemic of physical inactivity has now been pronounced as one of the leading global killers by the World Health Organization (WHO) (54). In fact, physical inactivity is associated with a wide range of adverse health conditions including cardiovascular disease (CVD), type 2 diabetes, obesity and hypertension (39). Furthermore, lack of physical activity (PA) is related to deleterious effects on body composition and the musculoskeletal system that include an increase in fat (adipose) tissue, decrease in lean body mass (LBM) and a reduction in bone mass and density. These declines are linked to an increased risk for all-cause morbidity, mortality and functional disabilities, all which are exacerbated in older adult individuals (30). As the main independent risk factor for the long-term morbidity, physical inactivity is directly related to CVD development, the top global cause for early death (34). Cardiovascular (CV) impairments associated with insufficient PA include acute declines in vascular function and aerobic capacity; alterations resulting in decreased functional ability in aging individuals to levels below those needed for daily function (6). Contrarily, an abundance of literature supports the beneficial role of regular PA participation for overall health. Exercise presents a physical challenge to the human body, which leads to a wide range of integrative physiological adaptations from the CV (63), respiratory (47) and musculoskeletal systems (76). These adaptive responses to exercise training aid in the development of overall physiological function and efficiency, which in turn improves health and promotes healthy aging. A negative dose-

response relation between PA and morbidity has been recognized, such that greater PA levels are associated with reduced all-cause mortality rates (44) and lower incidence of CVD, coronary heart disease and stroke (52). The Center for Disease Control and Prevention (CDC) recommends that adults participate in 150 minutes of moderate or 75 minutes of vigorous intensity aerobic PA per week, or a combination of both (55), in addition to partaking in resistance exercise training (RET) two times a week, concentrating on major muscle groups. These recommendations reflect the minimum exercise volume required to obtain the health benefits associated regular PA. These recommendations apply to adults of all ages, include those 65 years of age and older (55), for whom exercise represents an essential strategy for combating and preventing health-related deficiencies more commonly associated with aging adults.

While exercise training elicits general health and fitness benefits, specific adaptive responses have been found to be exercise modality and intensity dependent. Aerobic exercise training (AET) has been shown to decrease body fat percentage, fat mass, waist to hip ratio (74) and improve cardiovascular and aerobic capacity parameters including maximal oxygen consumption (VO_{2max}) (19). RET on the other hand promotes increases in lean body mass (LBM) (21), muscular strength (22) and muscle oxidative capacity (23). Both AET and RET have shown to provide osteogenic stimuli (25) which stimulates osteoblastic bone formation, thus improving bone mass, bone mineral density (BMD), and lessens the impact of physical inactivity and age-related bone loss. The traditional notion of modality-exclusive responses has been disputed by evidence of mixed adaptations to modified exercise protocols. Evidence of AET-induced musculoskeletal adaptations, which are traditionally reserved to RET, have

occurred in conjunction with aerobic adaptations in response to modifications to exercise mechanics. For example, the incorporation of a vertical incline challenge to running protocols resulted in supplementary muscle fiber recruitment and activation (5), subsequently inducing significantly greater muscular loading (26, 73) in addition to torque and power output (61). The introduction of this additional physiological challenge such as with uphill running has been thought to be an effective strategy to maximize the adaptions resulting from exercise training and raises the possibility for enhanced adaptive responses capable of altering physical inactivityrelated declines. Modifications to the intensity of exercise protocols may represent an alternative method to capitalize on exercise induced musculoskeletal adaptations. High intensity interval training (HIIT) is considered a time efficient substitute to moderate intensity aerobic exercise. HIIT is an exercise modality characterized by short work bouts performed at near or supramaximal intensities separated by periods of recovery. While work volume of exercise is low, HIIT has been shown to produce equal or superior positive effects on overall health and body composition which include losses in total and site specific body fat (4, 36), enhancements in fat oxidation during steady state exercise (4), increased LBM (36), improvements in cardiac function (67), insulin sensitivity (48), muscle oxidative capacity, endurance capacity (10) and lipid profiles (9). Sprint interval training (SIT), a subset of HIIT, has successfully generated enhanced musculoskeletal responses including peak and mean muscular power output (3), muscular strength development and slow to fast fiber type transition increases (20). Furthermore, SIT has resulted in improved cardiorespiratory parameters including endurance capacity and VO_{2max} [106]. These positive adaptive responses to HIIT occur from low exercise volume and short duration; characteristic which address a common perceived barrier for regular

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exercise participation: lack of time (40). For aging populations this barrier is even more apparent.

Despite the overwhelming evidence in support of the health benefits of regular exercise, (66, 74, 87) as well as the dangers associated with a sedentary lifestyle (41), a large portion of the population fails to meet these recommendations (77). While the aforementioned impairments affect the general population, particularly severe consequences are observed in women as a result of gender- specific physiological process and behaviors. Due to the significantly lower PA levels than those of males at all ages (78), women are more susceptible to the negative health effects of sedentary behavior than males. In addition, gender differences in the aging process such as the rise in CVD rates observed with the onset of menopause aggravate physical inactivity-related physiological declines (79), often leading to secondary impairments including poor aging. From an evolutionary biology perspective, aging is defined as "an age-dependent or age-progressive decline in intrinsic physiological function, leading to an increase in age-specific mortality rate and a decrease in age-specific reproductive rate" (1). The severity of age-related declines have been shown to be gender-specific, with women experiencing greater adverse effects in body composition and health related fitness parameters than their male counterparts. With the onset of menopause, women experience significant gains in fat mass, accompanied by selective redistribution of excess adiposity to the abdominal area [36], losses of LBM and muscular strength [13] and deteriorating bone integrity [16]. These alterations ultimately expose women to progressive frailty, functional impairment, increased risks for chronic disease and premature death (28, 59). The aging process in women is related to an acute rise in chronic diseases such as cancers, obesity, diabetes, Polycystic Ovarian

Syndrome (PCOS), osteoporosis and cardiovascular disease (CVD) (13, 59); with CVD accounting for the greatest number of deaths in women worldwide (62).

While aging is a maturational and irrevocable process, aging physiology research has challenged the sense of hopelessness associated with age-related physical decline by suggesting that physical deteriorations are at least in part, a result of physical inactivity and physiological disuse. Active Living [33] is a concept which promotes participation in regular PA for the conservation of health and functional ability into old age. This concept was extended by Orban, who incorporated vigorous PA to the Active Living definition as means to obtain optimal quality of life (QOL) and maximal health benefits from exercise [34]. In women undergoing the aging process, exercise training interventions have been proven successful at preventing and even eradicating anatomical and pathological alterations endured as part of the normal aging process. For example, exercise training has been shown to effectively ameliorate climacteric symptoms
[39], decrease fat mass, blood pressure, fasting glucose levels, triglyceride, cholesterol levels [40], increase LBM, and muscular strength (21) and significantly enhance lumbar spine and femoral neck bone mineral density (BMD) in osteopenic post-menopausal women (81). Physiological adaptations specific to AET, RET and HIIT are individually capable of preventing and reversing the specific consequences of aging, and would therefore have a positive effect on health and functional ability in older women. Exercise training programs encompassing both resistance and aerobic exercise modalities into one exercise training regimen in order to obtain adaptations specific to each are referred to as concurrent exercise training (CET), and have been found to produce synergistic enhancements of adaptations beneficial to health and body composition. These benefits include muscular hypertrophy, increased muscular

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strength (19) and VO_{2max} (49) to a greater degree than those resulting from RET or AET alone

(43). Furthermore,

CET protocols of high intensity have been shown to result in greater adaptive responses than

moderate intensity CET such as enhanced muscle endurance, fat loss, muscular hypertrophy and

strength improvements (19).

As evident by the growing body of evidence in support of a measured "boosting" effect

of high intensity and concurrent training on exercise-induced adaptations, an intervention

including both of these factors should result in optimal adaptive responses and beneficial health

effects. To date, no studies have assessed the effects of a high intensity CET program on older

women. Our intervention design incorporated high intensity, high impact, incline and strength

training principles with the intent of maximizing adaptive responses to a SIT and undulating

periodization resistance, CET program. The purpose of this study was to investigate the

physiological adaptations to a SIT-based CET protocol on recreationally active women ages

40‒64. In view of the extensive benefits generated by high intensity interventions, these modified

concurrent training protocols may conceivably produce training adaptations beneficial to

physiological function, fitness, and overall health. While such training programs would be

advantageous for any population subset, older women not meeting PA recommendations could

potentially experience an increased benefit due to gender specific declines observed with

increasing age. Additionally, high intensity and concurrent training studies employing all female

subject pools are lacking.

The findings of this study provide a deeper understanding of the physiological

adaptations and changes in body composition induced by this protocol in aging women. We

hypothesized that following 12 weeks of either level-grade or incline SIT concurrently performed with resistance training, significant improvements will be observed in CV, musculoskeletal and body composition parameters. Our study's adaptive responses would support efforts to maintain proper body composition, aerobic and functional capacity throughout the aging process and during late life.

CHAPTER II
REVIEW OF LITERATURE

The following scientific literature review presents an overview of the existing evidence of the physiological adaptations to specific exercise modalities and their interactions when completed concurrently and at high intensity by an older aged female population. In addition, we explored gender and age-specific responses to such program and the potential impact on women's health. A special focus was given to adaptive cardiovascular and body composition physiological adaptations.

Gender and Age Effects on Physical Activity Levels

Participation in regular physical activity is a well-recognized strategy to maintain health through the continuous adaptations which improve cardiovascular (63), respiratory (47) and musculoskeletal (76) function. According to the Center for Disease Control and Prevention (CDC), participation in regular physical activity is critical for older adults to ensure health and functional independence into late life (55). However, a decreasing trend in physical activity levels is observed with increasing age. Along with age come increased responsibilities associated with work and family obligations, often taking priority over extracurricular and leisure activities. From early life, a significant gender gap exists in levels of physical activity-Levels of physical activity in women are significantly lower than men at all ages (77). Furthermore, women's physical activity levels continuously decrease with increase age (71). While the declines in

health related fitness inherent to the process of aging are inevitable, inadequate levels of physical activity renders aging women at unnecessarily increased risk for major health complications. Physical inactivity is now regarded to as a serious pandemic as it is the fourth leading cause of death worldwide (42). Accumulating evidence supports the role of physical activity in ameliorating health declines including improvements in metabolic parameters (64), body composition (21) greater psychological status and general overall health (24). In fact, a strong dose-response relationship has been recognized, with increasing physical activity levels producing the greatest health benefits and symptom relief (68). Health promotion strategies with an emphasis in increasing physical activity levels in women are therefore of utmost importance in efforts to decrease morbidity and mortality associated with insufficient physical activity.

The process of Aging

The course of aging is composed of numerous physiological alterations that collectively influence health status. This multifactorial process results in pathology and subsequent death. As an inevitable consequence of long life, traditional beliefs suggest that aging is an innately detrimental and irrevocable process characterized by disability, precipitously fitness declines and chronic disease including metabolic abnormalities such as dyslipidemia, impaired glucose tolerance and type 2 diabetes mellitus (12). As defined by evolutionary biology, aging is "an age-dependent or age-progressive decline in intrinsic physiological function, leading to an increase in age-specific mortality rate (i.e., a decrease in survival rate) and a decrease in age specific reproductive rate" (1). Modern research findings regarding physiology of aging initiated a paradigm shift which aggressively challenged the concept that aging is an unalterable process of physiological deterioration. Is it possible that the declines and degenerative losses associated with normal aging be, at least in part, a result of physical inactivity and physiological disuse

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rather than overuse? The concept of Active Living (8) is a concept which promotes participation

in regular physical activity is as a part of daily life, including house and yard work. This concept

was extended by Orban, who incorporated vigorous physical activity to the Active Living

definition as means to obtain optimal quality of life (QOL) (53). He stated that: "Decline in

energy capacity with age is a normal phenomenon; abstinence from physical activity is not.

Unless one inspired to and embraces a vigorous active lifestyle that includes habitual

supplemental dosage of leisure or occupational physical activity, one increases the risk of

impairment, frailty, and morbidity along with a shorter life" (page 161) (53).

Gender Specific Aging

The physiological alterations associated with the aging process have been shown to be

gender-specific. As women age, they endure greater adverse physiological effects than their

male counterparts. The gender disparities compromising aging women are the result of the

combined effects of estrogen withdrawal at the onset of menopause and comparatively

substandard physiological parameters. Specifically, the decline in ovarian function characterized

by a physiological withdrawal of estrogen (72), which has been linked to cardiovascular disease

and osteoporosis development (56), the two leading mortality and morbidity causes in women.

This period is associated with adverse changes to body composition such as an increasing

overall fat mass, redistribution of excess adipose tissue around the visceral organs, LBM and

muscular strength losses and diminished bone mineral density and mass(70, 83). Loss of aerobic

capacity and cardiovascular fitness lead to a diminished functionality, poor health and increased

risk for all-cause morbidity and mortality. Furthermore, impairment of cardiorespiratory fitness

in particular in regards to VO_{2max} is significantly associated with increasing age and the

menopausal transition (18). Moreover, when compared to men, women have significantly lower

LBM (65), higher adiposity (32), lower BMD and smaller bones (60). Of particular concern for women is the mobilization of adipose tissue to the visceral region during midlife, alteration associated with increased risk for CVD development (13).

Body Composition Alterations of the Aging Process in Women

Fat mass

According to the Center for Disease Control and Prevention (CDC), 34.9% of Americans are obese, accounting for $147 billion of medical costs. Obesity is defined as excess body fat and is considered a contributing factor to disease and all-cause mortality. Obesity rates have been steadily increasing, particularly in aging women 60 years and older, from 31.5% (2003-2004) to more than 38% (2011-2012) (51). As women age, they experience a significant increase of not only fat mass, but its selective redistribution to the abdominal area (50). The resulting increase in visceral adiposity has been linked to increased risk for chronic disease (75). Evidence demonstrates that obese women are at increased risk of developing cancers, diabetes and CVD (59) than women of a normal body composition, supporting the link between excess body fat and disease. Individuals with a BMI equal to or greater than 30 kg/m^2 are considered obese. Although this measure does not account for variability in body composition, BMI provides a strong indication of body fatness and health status. The maintenance of a healthy body composition, particularly in regards of fat mass, should be a major priority for aging women. A longitudinal study investigating body composition changes during midlife revealed than on average, women experience increases in waist circumference of 5.7 cm and fat mass of 3.4 kg (70). These chronological changes were found to be related to Follicle Stimulating Hormone (FSH) levels, suggesting a strong correlation between fat mass and ovarian age(70).

Fat mass gains observed during this period are accompanied by adipose tissue redistribution to the abdominal area (75). Such fat mobilization results a phenotype of increased visceral fat associated with greater rates of metabolic syndrome (13) and PCOS (13, 25). Postmenopausal women exhibit elevated lipase activity in gluteal and abdominal adipose areas and lowered lipolysis responses which have been linked to increased obesity rates and the promotion of visceral fat storage (27).

Exercise training is associated with increased fat oxidation rates (74), improved RMR and lean mass (85) which supports healthy fat mass amounts and distribution. Following a 12month long resistance training intervention in elderly post-menopausal women, significant improvements in body composition were produced, including decreases in fat mass and improved musculoskeletal parameters (7). Comparative studies have investigated the effects of different exercise modalities on body composition. It was found that although aerobic exercise training has been proven effective in the reduction of whole and central adiposity among postmenopausal women (15), HIIT has been shown to produce similar lipid oxidation adaptations with significantly lower exercise training volume (9). These findings advocate HIIT as a time efficient strategy to obtain lipid metabolism adaptations comparable to those induced by traditional aerobic training. Specifically, HIIT has been shown to effectively reduce trunk and visceral fat (37).

Lean mass

Sarcopenia is a clinical condition characterized by skeletal muscle atrophy, loss of mass, strength and diminished function (17). This condition is aggravated by advancing age, with consequential functional deficits and decreased autonomy in older adults. In women, the

hormonal changes related to menopause (31) and age (22) are linked to LBM losses which consequently result in diminished muscular strength, lower RMR and restricted mobility. Moreover, the reductions in LBM lessens the muscular mechanical load on bones leading to deteriorating bone health (11). Muscular hypertrophy is the primary adaptation to resistance training, which leads to increase in muscular size, mass and strength. Longitudinal studies investigating physiological alterations that occur during menopause have repeatedly supported the role of regular exercise in preserving LBM in aging women. Following 9 months of resistance training, increases in LBM and RMR were observed (2), suggesting improvements in LBM are plausible despite of the age-related structural changes. Furthermore, this study reported average increases of 5% in RMR, which may counteract fat mass increments observed during the aging process.

While preserving LBM is important, maintaining muscular strength has been shown to be equally important and critical. Recent findings postulate that muscular strength losses are associated with serious health consequences including functional limitation, physical disability, multimorbidity and increased risk for mortality (14, 58, 80). This evidence strongly advocates the role of exercise training for the preservation of pre-menopausal LBM and muscular strength for the prevention of the negative consequences of age-related muscular declines.

Bone Health

Although critical for all populations, bone health is of particular importance for women. As a metabolically active organ, bone continuously undergoes resorption by osteoclasts as well as osteoblast-induced bone formation to maintain skeletal homeostasis (35). Bone mass and strength depend on the balance between these two processes which ultimately determine BMD. BMD is the main indicator of bone health and metabolism with normal adult BMD scores

ranging from 0.7 g/cm^2 for small bones and 1.08 g/cm^2 for larger bones. Peak BMD values

occur between the ages of 18 to 25, then decrease with age (11). Under normal conditions, these

processes work synergistically, sustaining skeletal mass and mechanical competence by

exchanging degraded tissue for newly synthesized bone. Contrarily, uncoupling of these

processes leads to increased bone turnover with diminished bone regeneration (23). As women

enter menopause, estrogen withdrawal induces an imbalance in bone remodeling, leading to

bone deterioration and subsequent development of osteoporosis (11). Osteoporosis is a disease

characterized by degeneration of bone microstructure, loss of bone mass and diminished

functional independence (69). The National Osteoporosis foundation states that an alarming

80% of osteoporotic patients are women, with one in two women over the age of 50 enduring a

bone fracture. Osteoporotic bone fractures are a main cause of morbidity and mortality and the

risk increases with age. A recent meta-analysis investigating clinical outputs in hip fractures

older patients, revealed a high mortality rate of 23.6% at two years post operation. (45),

emphasizing the debilitating and dangerous nature of osteoporotic fractures.

BMD is heavily affected by genetics but can also be modified by nutrition, health status

during growth years and of course, physical activity. During exercise, increased mechanical

load stimulates bone formation (29), whereas sedentary behavior is associated with reduced

mechanical load, increased bone resorption and lower BMD (38). In fact, studies advocate both

impact and nonimpact exercises as a strategy to successfully prevent bone loss in the lumbar

spine and femoral neck of pre and postmenopausal women (82). Eight months of moderate

impact resistance training in older women resulted in a significant increase in bone mass, as

well as improvements in handgrip strength, postural sway, and BMD at the femoral neck of

+2.8% (46). This increase in BMD is statistically and clinically relevant, and supports the role

of resistance training in producing adaptive responses capable of improving bone health, thus decreasing the for falls and bone fractures in older women. The severity of age and menopause induced bone abnormalities combined with the adverse effects of sedentary behavior supports the need for women to adopt and maintain a regular exercise routine at all stages of life.

Data shows that postmenopausal women are at a significantly increased risk for vertebral deformities, chronic back pain, height loss and osteoporotic fractures (16); which are considered to be one of the most disabling outcomes of aging in women. With 80% of osteoporotic patients being women, disease management programs to prevent bone loss are imperative to healthy longevity in this population.

Aerobic capacity

Insufficient physical activity is among the 10 leading global mortality factors and is considered a key independent contributor for CVD [1]. These risks are only exacerbated by the cardiovascular alterations commonly seen in aging women which include impairments to aerobic capacity and cardiorespiratory fitness to levels below those required for daily function (84).
Moreover, these age-related cardiovascular alterations risk for all-cause mortality and disease and ultimately loss of independence in older adults. (6). In particular, loss of maximal aerobic capacity has been shown to be an independent risk factor for all-cause and cardiovascular disease (CVD) mortality (6). Given the clinical implications of declining aerobic capacity, strategies to prevent and and/or attenuate age and physical inactivity-related declines in aerobic capacity are necessary for health and functionality throughout life.

High Intensity Exercise

Opportunely, exercise training interventions have been demonstrated to successfully prevent and even eradicate both symptoms and pathological alterations endured by women as part of the normal aging process. In menopausal women, exercise training has been shown to effectively ameliorate age-related health declines. These adaptive responses successfully counteract the physiological alterations associated with menopause and the aging process, thereby decreasing the risk for chronic diseases and improving health. A common trend has developed in the recent years of support for exercise of high to supramaximal intensities as a method to induce superior physiological adaptations and health benefits than exercise of moderate intensities.

In the last several years, training studies have produced accumulating evidence in favor of positive adaptations and health benefits as a result of HIIT. HIIT has been shown to produce similar exercise training adaptations as those associated with traditional high-volume endurance training in a significantly shorter period of time. In their 2008 study, Gibala and McGee (33) compared adaptive responses to HIIT to those resulting from a continuous, moderate intensity aerobic exercise training program of equal workload. Post-training adaptations from both programs were equivalent although the total exercise volume performed in the HIIT group was 10% of that completed by the continuous exercise group (33), suggesting that HIIT results in substantial physiological adaptations in a drastically more time-efficient manner.

HIIT generated fitness and health benefits include improvements in cardiac function (67), insulin sensitivity(48), muscle oxidative capacity, endurance capacity (9)and lipid profiles (9). When compared to endurance exercise, evidence indicates that HIIT results in parallel training adaptations including cardiovascular improvements in aerobic capacity (67). However, discrepancies exist concerning HIIT-induced improvements in maximal oxygen consumption

(VO_{2max}). Following a two week intervention consisting of 30-second Wingate sprints based

HIIT (SIT) in a group of young, recreationally active adults; significant improvements were

observed in citrate synthase activity, resting muscle glycogen content and an impressive 100%

increment in cycle endurance capacity (9). However, no significant changes in VO_{2peak} were

observed (10). Contrarily, the same protocol resulted in significant increases in maximal

oxygen uptake (L/min) and in Wingate power in a group of sedentary obese men

(86).Mechanistically, evidence suggests that HIIT-induced VO_2 improvements may originate

from peripheral cardiovascular adaptations, such as enhanced oxidative enzyme activity,

increased mitochondrial volume [21,22] and increased peripheral compliance (57); rather than

central adaptations typically associated with endurance training which are cardiac in nature.

HIIT generated fitness and health benefits include improvements in cardiac function (67),

insulin sensitivity (48), muscle oxidative capacity, endurance capacity (10) and lipid profiles

(9). Scientific evidence indicates that HIIT results in parallel aerobic adaptations when

compared to moderate intensity continuous exercise (67), however, discrepancies exist

concerning HIIT-induced increments in maximal oxygen consumption (VO_{2max}).

Concurrent Exercise Training

While exercise training elicits general health and fitness benefits, specific

adaptive responses have been found to be exercise modality dependent. Aerobic exercise

training produces improvements in cardiovascular parameters including maximal oxygen

consumption

(VO_2max) and aerobic capacity [19] while resistance exercise training (RET) leads to increased

LBM [21], muscular strength [22] and muscle oxidative capacity [23]. Furthermore, both

exercise modalities have been shown to provide osteogenic stimuli [25] which promotes

osteoblastic bone formation, thus improving bone mass, BMD, and lessening the impact of physical inactivity and age-related bone loss. Considering the benefits of both aerobic and resistance exercise, adopting a training regimen that integrates both exercise modalities is highly recommended. Concurrent exercise training models are specifically designed to incorporate aerobic and resistance exercise training with the goal of attaining positive adaptations inherent to each training modality [26]. A previous study by our research group investigated the effects of a 12-week modified concurrent exercise training intervention in a group of recreationally active young females. The aerobic portion of the traditional concurrent training model was replaced with High intensity interval training (HIIT) sprints in efforts to avoid blunted adaptive responses previously described in the literature [27]. HIIT is an exercise modality composed of short work bouts performed at near maximal or supramaximal intensities interspersed by rest periods; and has been shown to produce positive adaptations such as improvements in body composition [28], endurance capacity [29] muscle oxidative capacity [30] and overall health of comparable magnitude to aerobic training-induced adaptations; but in a significantly shorter amount of time [31]. The HIIT protocol chosen for our concurrent training intervention consisted of 8 repetitions of 20 second supramaximal intensity sprints followed by 10 seconds of passive recovery. An undulating periodization resistance exercise training protocol completed the intervention design. Following this 12-week exercise training program, significant improvements in muscular strength, power, LBM and VO2max were observed [32]. The magnitude of these adaptations was comparable to those observed in the resistance training only control group, confirming that this modified protocol evades the adaptive interference effect previously reported.

Conclusion and Purpose

A significant body of research has demonstrated the physiological adaptations of high intensity exercise when compared to exercise training of lower intensities in a wide range of populations. In addition to the health benefits associated with these adaptive responses, scientific evidence supports their role in ameliorating the detrimental effects of physiological aging on anatomical and physiological parameters, which in turn several affect functional ability in individuals of old age. In women, the combination of decreasing physical activity levels with age and gender differences in the process of physiological aging renders them at an increased risk for physiological and functional declines leading to poor aging. Of particular importance are alterations to body composition and aerobic capacity parameters related to physical inactivity and aging; which can be counteracted by adaptive responses to exercise training. While adaptive responses to individual exercise training modalities are well known, investigations in adaptations to high intensity training in aging women is lacking. The purpose of this study was therefore to determine the adaptive responses to a high intensity training protocol consisting of SIT and RET performed concurrently on recreationally active women ages 40-64.

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CHAPTER III
JOURNAL MANUSCRIPT I

Body Composition and Muscular Strength Adaptations to a Sprint Interval and

Resistance Concurrent Exercise Training Program in Inactive Adult
Women

ABSTRACT

PURPOSE: The purpose of this study was to assess the effects of a 12-week concurrent exercise

training program on body composition and muscular strength parameters including fat mass,

visceral adipose tissue, lean body mass, upper and lower body muscular strength and regional

bone mineral density (BMD) in recreationally active, aging women. METHODS: Recreationally

active women ages 40-64 (n= 76) volunteered for our study. The participants attended 3 training

sessions per week, at the same time each day. The concurrent exercise training (CET) protocol

consisted of high intensity level grade (0%) or incline (6%) sprint interval training (SIT) and an

undulating periodization resistance exercise training (RET) protocol. The SIT protocols were

performed at a speed and/or grade to achieve 95% of each participant's age predicted maximal

heart rate for 40 seconds followed by a 20 second passive recovery period. The resistance

protocol consisted of Workout A: Back squat, bent over row, and bench press and Workout B:

Squat Jumps, weighted lunges, the standing press and back extensions. Pre and Post training

dual X-ray absorption (iDEXA) scans were used for body composition assessment. RESULTS:

No significant between groups interactions were observed. Statistically significant

improvements were found for fat mass (CSIT0 30.1 ± 11.1 kgs to 29.2 ± 10.7 kgs, CSIT6= 27.6

± 8.6 kgs to

26.9 ± 7.5 kgs; P = 0.022), visceral adipose tissue (CSIT0 0.871 ± 0.797 kgs to 0.825 ± 0.671

kgs, CSIT6= 0.890 ± 0.757 kgs to 0.831 ± 0.666 kgs; P = 0.048). Additionally, statistically

significant improvements were detected in lower body muscular strength as evident by

improvements in the back squat 1 RM (CSIT0 49.2 ± 19.2 kgs to 91.1 ± 24.7 kgs; CSIT6= 41.2

± 15.9 kgs, to 86.8 ± 31.3 kgs, P < 0.0001), representing improvements of 85.2% and 110.7%

respectively as well as upper body strength measures as evident by the bench press 1 RM

(CSIT0 31.7 ± 9.2 kgs to 41.0 ± 7.75 kgs; CSIT6= 28.9 ± 7.7 kgs, to 38.1 ± 9.88 kgs, P <

0.0001), equivalent to improvements of 29.3% and 31.8% for CSIT0 and CSIT6 respectively.

CONCLUSION: While the inclusion of a vertical incline challenge does not lead to enhanced

adaptive responses, a SIT-based CET program is an effective strategy for body composition

improvements in recreationally active, aging women. The substantial muscular strength

improvements resulting from our intervention are of particular importance as muscular strength

losses are a strong predictor of multimorbidity and mortality.

INTRODUCTION

The United States National Center for Health Statistics estimates that about 15% of an individual's life is spent in an unhealthy state as a result of age-relate injury, disease or disability. Agerelated anatomical declines include muscular atrophy, decreased lean body mass (LBM) and muscular strength, bone mineral loss and increased total and visceral fat, all of which are associated with severe impairments in health status, aerobic capacity and physical function during later stages of life (12). Gender-specific responses reveal that women experience earlier onset of age-related bone density loss, and exhibit significantly lower overall and site-specific bone mineral density (BMD) than men at all ages (25). Evidence indicates that 15.4% of all females are diagnosed with Osteoporosis, increasing steeply to 34.9% of women 80 years and older; compared to 4.3% and 10.9% of men, respectively (11). Furthermore, women are particularly affected by sarcopenia and physiological disuse atrophy, incapacitating conditions related to disability, functional impairments and morbidity (5, 12). In fact, 47.6% of elderly women fall under the severe Class II sarcopenia, defined as individuals with appendicular skeletal muscle mass below 2 standard deviations of young adult mean values (40), condition correlated with functional impairments and disability (3, 40). Lastly, women experience average increases of 5.7 cm in waist circumference and 3.4 kg in overall fat mass (FM) (35) during midlife. This excess adiposity renders adult women at an increased risk in for the development of cardiovascular (CV) diseases among other chronic diseases (33) and functional impairments (40), risks which continually increase with age.

Prominent decreases in PA levels with increasing age, which are more pronounced in women, contribute to the physical declines related to normal physiological aging (34). Additionally, females are exposed to heightened risks for BC deteriorations resulting from gender-specific differences in

physiological aging, which further compound these alterations, during late life. Exercise-induced

adaptations are the basis of the concept of Active Living (30), which promotes regular physical activity

(PA) participation as an essential component for the conservation of proper BC. Active Living would

therefore be particularly advantageous for functional independence during late life in aging women.

Adaptive responses to aerobic exercise training (AET) include enhancements in cardiovascular (CV) and

respiratory function and fat loss (21), while resistance exercise training (RET) results in musculoskeletal

adaptations (23). Such adaptations are known to delay the age-related deteriorations of BC parameters

and reverse those caused by disuse. Combining AET and RET into a comprehensive training program is

referred to as concurrent exercise training (CET) (16), which has been found to lead to simultaneous

adaptations related to each modality. Alternatively, accumulating data supports physiological adaptations

to high intensity interval training (HIIT) comparable to, and even greater than moderate intensity

exercise despite lower exercise volume (6, 15).

RET is a potent anabolic stimulus to skeletal muscle growth leading to skeletal muscle

hypertrophy, increased LBM, improved neuromuscular efficiency, accelerated muscle contractile protein

synthesis and increased muscular strength in older adults (23). In aging women RET has resulted in

increases in maximal muscular strength and improvements in body composition such as increased fat

free mass (FMM) and decreased FM, adaptive responses supportive of the maintenance of physical

function

(28). Although AET is generally associated with CV adaptations and losses of FM, there is evidence of

AET-induced muscular hypertrophy (17) and myofibril functional improvements (18). Particularly,

modified AET protocols produce MS challenges which may lead to adaptive responses supportive of

FFM conservation. For example, incline running (INC) has been shown to increase muscular loading

(13, 36), torque and power output (4). Similarly, altering the intensity of AET such as high intensity

sprint interval training (SIT) has led to significant improvements in peak and mean muscular power

output (1) and slow to fast fiber type transitions, adaptations associated with enhanced strength

development.

Increases in exercise intensity have shown to produce augmented adaptive responses to exercise training beneficial to BC parameters. Bagley et al. found HIIT-induced losses in total body (-5.4%), trunk (-3%) and leg FM (6%) in addition to enhancements in maximal fat oxidation during exercise despite a weekly training volume of only 4 minutes (2). A meta-analysis of CET interventions revealed significant FM losses, with the greatest decreases in body fat occurring when the AET portion of the protocol is completed at a high intensity (38). It may be postulated that high intensity exercise training could represent an advantageous approach to FM loss compared to other exercise modalities due to intensity related secretion of growth hormone (GH) (32) which provokes an acute lipolytic response that facilitates losses of FM. Moreover, HIIT induced GH and epinephrine secretion result in greater post-exercise energy expenditure and fat oxidation (32), indicating greater fat loss from HIIT than lower intensity exercise. SIT may also lead to significant adaptive responses beneficial to bone tissue. Although the process of exercise-induced BMD improvements has been shown to occur with training durations of 7 to 36 months (19, 22), evidence of acute increases in bone turnover markers and anti-inflammatory cytokines has been observed after a single bout of a cycle ergometer SIT (26), suggesting that high intensity exercise may be an effective stimulus for bone formation. Furthermore, anabolic muscular stimuli including muscular hypertrophy and increased muscular strength were found to be amplified in CET training protocols performed at a greater intensity, resulting in superior improvements in lower and upper body muscular strength, muscular endurance and LBM (9) than when performed at lower intensities. Considering specific adaptations of CET and HIIT alone, it appears the integration of both modalities would result in a range of positive adaptive responses supportive of maintenance of BC, physical function and healthy aging.

The evidence presented above shows that a comprehensive CET program leads to adaptive responses capable of counteracting the deteriorating effects of aging on BC parameters. Furthermore, evidence indicates that high intensity CET may provide an optimal strategy to combat declines related to physiological aging. To our best knowledge, no previous studies have utilized high intensity CET as a mean to maximize adaptive responses in a population of worsening BC parameters such as aging

women. The combination of uphill and level-grade SIT and RET integrates a range of physiological challenges which may promote beneficial BC adaptations. Hence, the purpose of this study was to investigate the physiological adaptations to a SIT-based CET intervention in women ages 40 through 64 whose PA does not exceed recreational levels. The findings of this study provide valuable evidence of the adaptations that this training model produces to optimize women's fitness and health; imperative factors for a functional and independent lifestyle.

METHODS

Experimental Approach to the Problem

In order to assess the specific adaptations of body composition and muscular strength to a sprint interval based-concurrent exercise training intervention in recreationally active, adult women, FM, LBM, BMD and maximal upper and lower body muscular strength were assessed pre and post exercise training in two experimental groups. Additionally, we investigated the differential effects of vertical incline versus level-grade sprints in the sprint interval portion of the training protocol on the parameters of interest. A total of 53 participants (52.7 ± 7.1 years) were randomized into one of two experimental groups: concurrent resistance with no incline HIIT sprints (CSIT0) and concurrent resistance with 6% incline HIIT sprints (CSIT6). Randomization was completed in a matched pairs design based on baseline VO_{2max} values. Body composition parameters were assessed via Lunar dual energy X-ray absorptiometry (iDEXA) scan and included total, visceral adipose tissue (VAT), lean body mass, regional BMD (in g/cm^2) for the anterior-posterior (AP) lumbar spine and femoral neck (FN). In addition, upper and lower body muscular strength measures were assessed through a Walten formula estimation of the 1 repetition max of the bench press and back squat respectively.

Subjects

Recreationally active female volunteers between 40 and 64 years of age were invited to participate in a 12-week SIT-based CET study. Individuals considered to be recreationally active were defined as those who engage in moderate intensity aerobic or resistance physical

activity no more than 3 days a week, for a duration no longer than 30 minutes as determined by a current physical activity questionnaire. Participants completed the Physical Activity Readiness Questionnaire (PAR Q) screening to ensure proper health status including no prior history of CVD, confounding orthopedic problems, currently medications that may interfere with experimental variables, or other personal or health issues that would be contraindicated for participation. In order to be eligible for participation in this study, participants must meet the minimum requirements of: maximal aerobic capacity (VO_{2max}) $\geq$ 20 ml•kg-1•min-1, BMD $\leq$ 2.5 standard deviations (SD) from reference value for age group, able to safely perform the exercise protocol and available to regularly attend 12 weeks of the exercise training intervention.

Participant recruitment was focused in the local community via targeted e-mails, flyers and word of mouth. Seventy-six participants met the inclusion criteria and volunteered to participate. During preliminary assessments, eligible participants were asked to read and sign an informed consent document agreeing to participate in the study, which was reviewed and approved by a University Institutional Review Board. Participants were eliminated from the analysis if more than three exercise training sessions were missed. An all-female population is warranted for this intervention as no research study to date has investigated the effect of a high intensity CET on body composition and muscular strength in adult women.

Procedures

Preliminary Assessments

Eligible participants were asked to read and sign an informed consent. VO_{2max} assessment was completed to determine each participant's initial VO_{2max} using the Bruce protocol.

Participants who met the minimum $VO_{2\ max}$ requirement of 20 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ were evaluated for the remaining assessments including anthropometric measures. Eligible participants were scheduled to return to the laboratory for maximal muscular strength testing of the lower and upper body. One-Repetition Maximum (1 RM) values were estimated from a 3 repetition maximum for the squat and bench press respectively. During this time, participants learned the study's exercise protocol including safe treadmill practices and proper lifting techniques.

Dual-emission X-ray Absorptiometry

Anthropometric measures were collected prior to body composition scanning. Participant's weight was assessed with a calibrated electronic scale (Michelli Scales, Harahan, LA) and to the nearest 0.1 kg while height was measured to the nearest 0.25 inches using a standiometer. Body composition assessment was performed via Lunar dual energy X-ray absorptiometry (iDEXA) scan (GE Healthcare Lunar, Madison, WI), which utilizes a fan beam x-ray and different photon energy levels with distinctive attenuation profiles to detect different body tissue, then creates high resolution images that identify their amounts specific distribution in the body. Total and regional FM, LBM, body weight (BW) were measured by iDEXA. Additionally, densitometry analysis was used to assess regional BMD (g/cm^2) for the anterior posterior (AP) lumbar spine and femoral neck (FN). All iDEXA measurements were carried out by qualified research study personnel.

Maximal Muscular Strength

At baseline, lower extremity muscular strength was assessed with an estimated 1 RM for the back squat while upper extremity muscular strength was gauged through the bench press 1RM.

Due to possible unfamiliarity with resistance exercise, participants were instructed on and practiced proper lifting techniques. Initial back squat 1RM assessment began with 10 repetitions of a body weight squat followed by 5 back squats using a 45 lb. barbell. Foam barbell covers were available for the convenience of participants. After a 2-minute break, 5 additional repetitions were completed at 50% of the participant's estimated 1RM for the back squat. Following an additional 2-minute rest period, 3 repetitions were completed at an estimated 70% of 1RM. Subsequent sets of progressively increased weight were completed until three repetitions were performed with proper form at near maximal weight. Each of these sets was separated by a recovery period of 3 minutes. Three RM values were utilized to estimate 1 RM values through the Wathen equation. A similar approach was utilized for the estimation for the bench press 1 RM. A conservative loading approach was taken due to initial fitness levels of participants.

Post Testing

Post intervention testing was conducted immediately following the completion of the 12week intervention. Values of all variables were reassessed on week 13.

Study Design

After completing preliminary assessments, participants were pair-matched by VO_{2max} and assigned to one of two experimental groups: concurrent resistance exercise and level-grade (0%) incline SIT (CSIT0) or concurrent resistance exercise and 6% incline grade SIT (CSIT6). Participants attended three exercise training sessions per week, at the same time during the day on a Monday, Wednesday and Friday schedule for twelve weeks. The order in which the SIT and resistance exercise portions of the protocol was alternated between sessions in order to

avoid potential order effects. Each training session began with a general warm-up composed of dynamic mobility and active stretching. Following the completion of each training session, flexibility and core protocols were completed.

Experimental Intervention

High Intensity Sprint Interval Training (SIT):

The design of the SIT protocol was chosen to maximize adaptive BC responses consisting of 2 sets of three 40-seconds high intensity sprints immediately followed by a 20 seconds of passive recovery during the first 6 weeks of the intervention, while an additional set was introduced during the last 6 weeks. Each set was separated by a 1-minute passive recovery. The sprints were performed at a specific speed and/or incline to induce cardiovascular responses equal to 95% of the participant's maximal heart rate (HR_{max}) according to initial Bruce Protocol testing. The sprint sets were preceded by a 3-minute walking warm up at 3.0 MPH. After the conclusion of the SIT protocol, a walking cool down of equal duration and speed was completed. Participants were instructed to place their hands on the treadmill handle bars to support their body weight while transitioning between sprints and the passive recovery. No incline (0%) was utilized for the CSIT0 group, while the CSIT6 group ran at 6% incline. The purpose of the addition of incline to the high intensity intervals was to investigate the possible enhanced activation and recruitment for muscle fibers as a strategy to ameliorate BC declines common of our target population. The benefits of uphill running have been shown in exercise capacity improvements (time to exhaustion), increased muscular torque, power output and enhanced running performance by increased muscular loading (13, 36); adaptations which may lead to significant gains in muscular strength.

Undulating periodization resistance training protocol

An undulating periodization model for resistance exercise training was utilized in order to impose fluctuating stimuli and in turn, neuromuscular overload. The intensity and volume of undulating periodization models are continuously modified to stimulate musculoskeletal adaptations (31). The undulating protocol chosen for this study was composed of two individual protocols with two individual loading and repetition phases.

The endurance phase consisted of high volume and low repetitions which is conducive to increases in LBM. The strength phase was composed of higher loads and less repetitions than the hypertrophy phase. The muscular endurance phase encompassed 3 sets of 10 repetitions at 65%,
70% and 75% of each participant's 1RM for the back squat and bench press, whereas the strength phase was composed of 3 sets of 6 repetitions at 75%-80%-85% of calculated 1 RM for each of the lifts. The muscular hypertrophy phase was comprised of 3 sets of 8 repetitions at 75%-80%-85% of calculated 1 RM for each of the lifts respectively (Table 4). All training sets were proceeded by a warm-up set or 5 reps at 50% of 1 RM. One RM values were extrapolated from submaximal 3 repetition testing for the back squat and bench press using the Wathen formula, a valid calculation for the prediction of maximal strength for this age group. Training protocols A and B were performed on alternate training days throughout the study such that each training scheme was completed 3 times every two weeks, with the number of repetitions and load being altered every third training session (Table 3).

- *Workout "A"*: Back Squat, Bench Press and Bent-over Row
- *Workout "B"*: Squat Jumps, lunges, standing shoulder press and back extensions.

All exercises were specifically chosen for this protocol to promote physiological adaptions in the targeted population.

Statistical Analysis

The effects of training on dependent variables (LBM, FM, VAT, Anteroposterior (AP) spine BMD, Femoral neck (FN) BMD, 1RM Squat and 1 RM Bench Press) were analyzed using a repeated-measures analysis of Variance (ANOVA) with one between- subject factor (Experimental group, with 2 levels CSIT0 and CSIT6) and one within-subjects factor (time, with 2 levels, pre and post). Experimental group by time interactions and simple main effects were analyzed. Standard statistical methods were used for the calculation of means, standard deviations (SD). Descriptive statistics are presented as mean $\pm$ SD. The significance level for this study was set at $P < 0.05$.

RESULTS

A total of 53 women participants completed the 12-week study. Thirteen participants withdrew from the study for personal reasons or injuries unrelated to the study or failed to meet the study's attendance requirements. No significant differences were observed between experimental groups with respect to initial anthropometric or body composition values (P> 0.05).

Baseline descriptive characteristics of the participants are presented in Table 3.

Body Composition Data

No group-by-time interactions were detected for any of the BC parameters. However significant differences in FM were observed between pre and post training intervention for both groups (CSIT0= 30.1 ± 11.1 kgs to 29.1 ± 10.7 kgs, p =0.02; CSIT6= 27.2 ± 8.7 to 26.4 ± 7.6 kgs). VAT decreased significantly in the CSIT0 group from 0.871 ± 0.797 kgs to 0.825 ± 0.671 kgs and in the CSIT6group from 0.890 ± 0.757 kgs to 0.831 ± 0.666 kgs; (P= 0.048). No significant interaction between groups were found for LBM, AP BMD or FN BMD (P = 0.092, P = 0.612, P= 0.881) or with time (P = 872, P = 0.565, P= 0. 670). Covariance for change in body weight were performed, but no significant interactions were found for either of these 3 variables.

Pre and post intervention body composition changes are presented on table 4.

Muscular Strength Data

Despite a lack of change in LBM, significant increases in upper and lower body strength measures were found in both groups following the 12-week exercise training intervention. Analysis of the muscular strength data revealed no group-by time-interactions. Baseline 1 RM back squat values for the CSIT0 increased significantly ($P < 0.0001$) by 88.5%. Similarly, the CSIT6 group increased lower body strength by 110.8% ($P < 0.0001$). Upper body strength measures were significantly greater post intervention for both experimental groups ($P < 0.0001$) as evident by the 29.2% and 31.7% increases in the 1 RM Bench press for the CSIT0 and CSIT6 groups respectively. Upper and lower body muscular strength changes presented in figures 1 and

2.

DISCUSSION

This study was designed to test the effects of a 12-week high-intensity concurrent incline or level-grade SIT and undulating periodization RET program on BC and muscular strength in recreationally active, adult women. The completion of our intervention resulted in significant reductions in FM ($P = 0.02$) and VAT ($P= 0.048$) in both experimental groups. While no significant changes in LBM were detected, significant improvements were observed in upper and lower body strength demonstrated by the 1 RM bench press and back squat pre versus post intervention scores ($P < 0.0001$). These effects were seen independent of the experimental group to which participants were randomly assigned, indicating that both incline and level-grade-SIT effectively produced similar body composition and muscular strength changes in this cohort.

Fat Mass

Significant decreases in overall FM were observed in both experimental groups. In regards to percent body fat, a decrease from 40.6% to 39.5% was observed in CSIT0 while participants in CSIT6 percent fat mass was reduced from 39.4% to 38.6%. While previous investigations have sought to determine the effects of CET on body fat, no previous studies have determined these outcomes in adult females ages 40 through 64. Our findings are comparable to those of other training interventions of similar duration. Glowacki et al. investigated the differences in training outcomes of RET, AET and CET during a 12-week training study in young, untrained males. It was found that the CET experimental group experienced significant

losses in percent body fat of 1.3%, protocol which consisted of incremental AE and RET portions of moderate intensity (16).

In a 2014 study, Davitt et al found that 8 weeks of a CET comprised of moderate-high intensity AET and RET in young females did not result in significant changes in FM (10). Although shorter in duration, their exercise training intervention consisted of 4 sessions per week at moderate intensity, resulting in comparable exercise training volume among studies. Our findings corroborate the effectiveness of high intensity exercise as a fat loss strategy and support findings from our previous studies in young females indicating the beneficial effects of high intensity concurrent exercise training interventions for reductions of FM. Considering the high intensity nature of our intervention, the literature supports that the FM losses observed in the current study may be in part due to increased secretion of Growth hormone (GH) which have been shown to increase linearly with exercise intensity (32) and provoke an acute lipolytic response that facilitates losses of FM. Moreover, HIIT-induced GH and epinephrine secretion result in greater post-exercise energy expenditure and fat oxidation (32). Significant decreases in VAT were detected in both groups, indicating a deviation away from the central adiposity phenotype characterized by concentration of "active fat" in the visceral area is associated with the development of chronic diseases such as for metabolic syndrome (7), cancers, diabetes and cardiovascular (CV) disease (33). The post training reductions in body fat observed were significant for time (P = 0.002), however no significant interactions were observed between groups (P = 0.620). These findings indicate that no supplementary benefits result from uphill SIT in regards to fat loss, however the fat loss resulting from this SIT-based CET confirms its potential role in decreasing the risk of obesity-related health issues in adult, overweight females.

Lean Body Mass and Muscular Strength

Following the completion of the 12-week high intensity CET intervention, no significant interactions were observed for LBM between groups or for time. In contrast to other CET studies which resulted in increases in LBM (10, 16, 24), the lack of muscular mass gains could be due to population-specific factors. As women age, they experience sarcopenia, the age-related declines in muscular mass and strength (37), which is exacerbated by physiological disuse. Thus rather than muscular mass gains, regular exercise training may nonetheless support the maintenance of LBM in a population at risk for gender-specific and aging-related LBM losses. It could also be plausible that due to the degenerative muscular effects affecting this cohort, a longer duration of training may be required for significant LBM gains. Gender-based comparisons to CET in young individuals indicated that males show greater increases in total body and leg LBM as well as in cross sectional area of lower body musculature when compared to females (8). These findings were attributed to physiological gender differences as well as a significantly reduced caloric intake during training in the female experimental group. Dietary intake was not controlled for in our intervention, thus cannot be ruled out as a contributor to the lack of LBM gains as well as the significant FM losses observed in our cohort.

Despite the lack of changes in muscle mass, notable increments in muscular strength were achieved in both experimental groups. Losses of muscular strength are strongly associated with multi-morbidity functional limitations and physical disability in middle aged and older adults (3, 12, 40). Contrarily, Fitzgerald et al indicated significantly lower rates of all-cause mortality in individuals categorized as having moderate or high muscular fitness (14). Thus, the increases in lower and upper body strength resulting from our intervention indicate substantial functional ability improvements and a lowered risk for morbidity and mortality in our cohort

despite a lack of change in LBM. Improvements in lower body muscular strength expressed as percent change of 85.1% and 110.8% were observed in the CSIT0 and CSIT6 groups respectively as evident by pre and post training 1 RM values for the back squat (Pre= CSIT0 49.2 ± 19.2 kgs to 91.1 ± 24.7 kgs; CSIT6 = 41.2 ± 15.8 kgs, to 86.8 ± 31.3 kgs, P < 0.0001). Similar trends were observed for upper body muscular strength. While the CSIT0 1 RM bench press values increased from 31.7 ± 9.2 kgs to 41.0 ± 7.8 kgs, baseline upper body strength values for the CSIT6 group were 28.9 ± 7.7 kgs and 38.1 ± 9.9 kgs (P < 0.0001); indicating percent changes of 29.2% and 31.7% respectively. Although CSIT6 showed larger muscular strength gains for both lower and upper body musculature than CSIT0, between group interactions did not reach statistical significance. An intervention of longer duration may be necessary for incline-specific adaptations to occur. Similar lower and upper body muscular strength findings resulted from an eight-week long CET intervention by Davitt et al. in young females (10), suggesting that our intervention provided the appropriate stimulus for muscular strength gains despite of age-related neuromuscular declines. In another study, high intensity sprints and strength training CET completed in young professional soccer players resulted in lower and upper body strength percent increases of 20.3% and 7.2% respectively (39). When compared to these findings, our intervention seems to have led to larger improvements in muscular strength than observed in young, professional soccer players, which is likely due to the much lower baseline fitness levels of our cohort; thus greater physiological ability for improvements.

Bone Mineral Density

At the completion of the 12-week intervention, our data showed no significant interactions between groups or for time for the FN (P = 0.670) or AP spine BMD (P= 0.529).

While we understand that improvements in bone health parameters from our intervention and older women were not likely, we wanted to investigate the possibility based on results from a similar intervention on young women between the ages of 19 and 34 years which produced significant improvements in overall BMD. An important factor to consider is that under normal conditions, BMD is the product of continuous osteoclast-induced bone resorption and osteoblastic bone formation reactions at equilibrium (29). These conditions are favorable for exercise training-induced stimulation of bone formation while the accelerated bone resorption seen in older women impedes normal adaptive responses to exercise. Meta-analyses of the effects of exercise training on bone tissue reveal that high-impact exercises may be superior to resistance training for increasing bone mass, while resistance training has the advantage targeted loading at both hip and spine (27). With this knowledge in mind, our study was specifically designed to include exercises which inherently contribute the necessary stimulus for bone formation. Due to the high impact nature of the SIT protocol, it can be assumed that this portion of the concurrent training program provides the anabolic stimulus necessary for increasing bone mass and reinforced by the RET portion of the intervention. However, exercise training studies revealing significant BMD improvements were those of durations of 7 to 36 months (19, 22), suggesting that longer interventions may be required for bone improvements in this specific population. Interestingly, acute responses to a single bout of a cycle ergometer SIT (26) such as increased bone turnover markers and anti-inflammatory cytokines have been observed, indicating that HIIT may stimulate bone adaptive responses at a faster rate than exercise training of lower intensities. In the current study, acute responses to SIT were not assessed, therefore this cannot be confirmed.

Other functional improvements

While we sought to recruit physically inactive to recreationally active female participants, baseline VO_{2max} values indicated that the large majority of our participants fell under the "sedentary" physical activity category for their age group (20), and consequently displayed low levels of overall fitness. Inadequate muscular fitness, poor balance and inflexibility were manifested by the inability of some participants to perform exercises in the RET protocol properly or without assistance. In additional to the back squat and bench press, the RET protocol also included exercises such as back extensions, overhead shoulder press, bent over row, core strengthening protocol, flexibility training and lunges. While the statistical analysis was limited to traditional upper and lower body muscular strength measures of the 1 RM back squat and bench press, additional muscular fitness benefits were observed as evident by performance improvements of the remaining RET exercises. Due to a range of muscular strength and stability levels, some participants began the training program performing static lunges while holding onto the wall for balance while others were able to perform unweighted walking lunges. Following the completion of the CET intervention, exercise training-induced muscular improvements were apparent, as the participants were able to perform unassisted, weighted-barbell walking lunges with improved form and greater resistance. Similar developments were observed with the bent over row and overhead shoulder press, lifts which participants performed with progressively increasing weight and improved form. Moreover, our participants reported greater ease when performing back extensions, core exercises and the flexibility protocol. Although pre and post assessment of these exercises was not included in the statistical analysis, these performance improvements were indicative of overall fitness enhancements. The total number of CET sessions for the 12-week duration of this intervention equates to a total of only 36 hours of combined SIT and RET exercise training. Considering the

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substantial functional capability benefits resulting from such low volume of exercise, it can be

proposed that the combination of high impact SIT and a comprehensive RET protocol

effectively leads to enhanced fitness parameters conducive to functional aging in a population

that may otherwise be at risk for loss of independence, disability and health complications

associated with a sedentary lifestyle late in

life.

Conclusion

In summary, the combination of high intensity interval sprints and resistance training

into one, inclusive, 12-week exercise training program led to significant improvements in BC

parameters and muscular strength beneficial to overall physical function in aging women whose

physical activity levels fail to meet recommendations. Women with excess adiposity are at

increased risks in for the development of metabolic syndrome (7), cancers, diabetes and

cardiovascular (CV) disease (33), and the risks continually increase with age. Therefore, an

exercise training intervention resulting in significant FM losses, such as ours, reduces the risk

for all-cause morbidity and mortality for aging females. While the lack of increases in LBM is

certainly unanticipated, it does not signify the absence of positive physiological adaptations to

our training intervention. It is imperative to reference the progress in muscular strength and

exercise performance resulting from this high-intensity CET program. Consequently, such an

intervention design should be considered as an effective strategy for adult females to reduce the

age-related deterioration of physical function, including the risk for fall and injuries, and may

favor healthy and functionally independent aging process. Future studies should investigate

whether a longer duration high intensity CET may lead to incline-specific significant increases

in LBM and BMD in aging women, a population of deteriorating body composition parameters.

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JOURNAL MANUSCRIPT II

The Effect of a Sprint Interval and Resistance Concurrent Exercise Training Program on Aerobic Capacity of Inactive Adult Women

ABSTRACT

The purpose of this investigation was to examine the effects of high-intensity concurrent exercise training (CET) consisting of sprint intervals (SIT) and undulating periodization resistance exercise (RET) on aerobic capacity in recreationally active, adult females. Fifty-three participants were pair-matched into level-grade (CSIT0) or 6% incline (CSIT6) CET experimental groups according to preliminary maximal aerobic capacity (VO_{2max}) assessment via the Bruce protocol. This 12-week intervention consisted of 3 sessions per week of SIT and RET completed concurrently, in alternating order. SIT consisted of 2 (weeks 1-6) or 3 (weeks 7-12) sets of three 40s sprints interspersed with 20s rest at specific intensities to evoke cardiovascular

(CV) responses equivalent to 95% of age-predicted maximal heart rate (HR); each separated by 1-min passive recovery. Speeds were modified to maintain target HR in accordance to CV adaptations. Post-training revealed significant improvements in both experimental groups ($P < 0.05$) for VO_{2max} (2.11 ± 0.390 to 2.29 ± 0.382 L•min^{-1}; 2.03 ± 0.382 to 2.09 ± 0.561 L•min^{-1}, $P < 0.0001$), Tmax (490.5 ± 102.3s to 542.7 ± 81.5s; 503.2 ± 75.4s to 541.8 ± 77.0s, $P < 0.0001$) and Vmax (5.1 ± 0.92MPH to 5.9 ± 0.90MPH; 4.3 ± 0.68MPH to 4.9 ± 0.64MPH, $P < 0.0001$) respectively. No significant between-group interactions were detected for any other variables.

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Our SIT based CET intervention represents an effective strategy to induce significant CV adaptations in older women as evident by improvements in aerobic capacity parameters beneficial to overall health and critical for functionality into old age; an important concern for aging women.

Key Words: HIIT, Concurrent, Sprints, Aging, Females, VO_{2max}

INTRODUCTION

The process of aging is characterized by a gradual physiological and anatomical breakdown of bodily systems, resulting in increased risk for chronic diseases and ultimately loss of functional independence (2). While these impairments affect the general population, particularly severe consequences are observed in women as a result of gender- specific behavioral patterns and physiological processes. Participation in regular physical activity (PA) is strongly recommended in aging populations for protection against chronic diseases, body composition and functional declines (12). However, women's PA levels drop as they transition into adulthood, continue to decline thereafter (26), and are significantly lower than those of males at all ages (29). Consequently, fewer older women obtain the health benefits of PA and are more susceptible to the negative health effects of sedentary behavior than their male counterparts. Furthermore, gender differences in the aging process may pose an increased risk for age-related complications in this cohort, as cardiovascular disease (CVD) rates have been observed to rise with the onset of menopause (30).

Over the years, incline running (INC) has been a popular training strategy advocated by coaches and well-recognized running magazines for athletic performance improvements. It has been postulated that INC results in superior musculoskeletal (MS) and aerobic (AE) adaptive responses resulting in increases in muscular strength of the hamstrings, glutes, and hip flexors (6) as well as AE capacity (16) to a greater degree than level-grade running. With that assumption, INC has been commonly integrated into exercise training programs for competitive

athletes and collegiate teams despite the lack of scientific evidence supporting these claims. The

majority of research on the topic has been mostly focused on biomechanical and kinematic data

(1, 23, 27), with only a few studies (7, 11) having investigated the physiological adaptations to

this training modality, in highly trained populations only. Biomechanical investigations have

shown that adding a vertical challenge to traditional level-grade running leads to phase-specific

increments in lower-body musculature activation, and increased joint power movements and

angular velocities at the ankle, knee and hip joints (7, 27) as well as increased work output at the

hip (23) when compared to level-grade running. These findings indicate distinctive kinematics

and acute MS responses to INC but do not denote adaptive physiological responses. INC-

induced AE capacity adaptations exceeding those resulting from level-grade training have also

yet to be determined. Although INC has been shown to result in improved indices of running

economy including VO_2 (8) and increased time to fatigue (T_{max}) when running at the velocity

associated VO_{2max} (7, 8), these enhancements were not significantly different than those induced

by level grade running.

Although we do not understand the effects of INC as a training modality, physiologists

utilize INC in maximal AE capacity (VO_{2max}) assessment protocols as a method to achieve the

required exercise intensity to obtain maximal VO_2 values as it has been found that INC elicits

higher VO_2 values than testing protocols composed of level-grade running with increasing

speeds (31). The incorporation of INC allows for high intensities of exercise to be attained at

lower velocities and maintained for longer periods of time than high speed exercise as it is

hypothesized that during speed-only protocols, individuals will eventually be unable to sustain

incremental speeds prior to reaching their VO_{2max}. This concept can be extended to High

Intensity Interval Training (HIIT), a novel exercise modality consisting of repeated high or

maximal efforts work bouts (e.g. $\geq 90\%$ VO_{2max} or HR_{max}), each followed by a recovery period. Accumulating evidence reveals that exercising at such intensities leads to greater health and fitness benefits including improvements in CV and AE capacity parameters (4, 25) than those resulting from moderate intensity exercise training. Previous research by our laboratory revealed that an 11-week long, Sprint Interval Training (SIT) and undulating periodization resistance exercise training (RET) concurrent exercise training (CET) intervention in young, sedentary women yielded significant gains in maximal muscular strength, power, endurance capacity and VO_{2max} (15), indicating that in young, sedentary females, a SIT-based CET program results in significant AE capacity and MS adaptive responses in a time efficient manner. Consequently, HIIT may represent a highly effective exercise-training strategy for populations of low cardiorespiratory fitness. However, HIIT may not be suitable for all cohorts such as aging individuals who exhibit sarcopenia. This age-related loss of muscular mass and strength is further complicated by a selective loss of type II fibers, (17); muscle cells utilized during maximal force and high speed exercises. Thus, traditional HIIT protocols are problematic for aging populations who may no longer have the proper muscular composition to perform high intensity exercises.

In view of the benefits associated with HIIT and those claimed to result from INC, a modified INC-SIT approach may prove highly beneficial for aging cohorts of declining physiological function. The purpose of this study was to determine the physiological adaptations, specifically in regards to AE capacity, to an INC and level-grade SIT intervention in untrained, adult women. This study will for the first time, seek to determine the differential adaptations resulting from INC vs. level grade SIT, specifically as it refers to AE capacity; a great concern for sedentary and aging populations. Furthermore, no investigations have

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previously examined the physiological responses to a high intensity CET intervention in

recreationally active, aging women, a cohort of declining physiological function.

METHODS

Experimental Approach to the Problem

To investigate the effects of a sprint interval based-concurrent exercise training intervention on aerobic capacity in recreationally active, adult women, aerobic capacity parameters and cardiovascular adaptations were assessed pre and post exercise training in two experimental groups. As a secondary aim, we sought to determine whether the inclusion of a vertical incline component to the sprint interval portion of the training protocol would result in differential adaptive responses in aerobic capacity. To analyze these effects, 53 participants (52.7 ± 7.1 years) were randomized into one of two experimental groups: concurrent resistance with no incline HIIT sprints (CSIT0) and concurrent resistance with 6% incline HIIT sprints (CSIT6). Randomization was completed in a matched pairs design based on baseline VO_{2max} values and evaluated before and after the 12 week intervention in the following variables: absolute maximal oxygen consumption (VO_{2max} in $L \cdot min^{-1}$), maximal time (T_{max}) on the treadmill during Bruce Protocol assessment of VO_{2max} expressed in seconds (s) and maximal velocity (V_{max}) required to induce CV responses of 95% of age-predicted maximal heart rate (HR_{max}) during SIT, in miles per hour (MPH). Pre and post- intervention testing was overseen by the trained investigators to ensure participant's safety.

Subjects

Recreationally active female volunteers between 40 and 64 years of age were invited to participate in a 12-week SIT-based CET study. Individuals considered to be recreationally

active were defined as those who engage in moderate intensity aerobic or resistance physical activity no more than 3 days a week, for a duration no longer than 30 minutes as determined by a current physical activity questionnaire. Participants completed the Physical Activity Readiness Questionnaire (PAR Q) (5) screening to ensure proper health status including no prior history of CVD, confounding orthopedic problems, currently medications that may interfere with experimental variables, or other personal or health issues that would be contraindicated for participation. In order to be eligible for participation in this study, participants must meet the minimum requirements of: maximal aerobic capacity (VO_{2max}) $\geq$ 20 ml·kg^{-1}·min^{-1}, BMD $\leq$ 2.5 standard deviations (SD) from reference value for age group, able to safely perform the exercise protocol and available to regularly attend 12 weeks of the exercise training intervention.

Participant recruitment was focused in the local community via targeted e-mails, flyers and word of mouth. Seventy six participants met the inclusion criteria and volunteered to participate. During preliminary assessments, eligible participants were asked to read and sign an informed consent document agreeing to participate in the study, which was reviewed and approved by a the University Institutional Review Board. Participants were eliminated from the analysis if more than three exercise training sessions were missed. An all-female population was warranted for this intervention as no research study to date has investigated the effect of level grade vs. INC SIT based CET on physiological variables in middle aged adult women.

Procedures

Preliminary Assessments

Anthropometric measurements included height, body mass, hydration status and body composition. Anthropometric assessment of body mass was performed with a calibrated

electronic scale to the nearest 0.1 kg while height was measured to the nearest 0.25 inches using a standiometer. Body composition and bone mineral density (BMD) measurements were performed via Lunar dual energy X-ray absorptiometry (iDEXA) scan (GE Healthcare Lunar, Madison, WI). Additional assessments included baseline maximal aerobic capacity (VO$_{2max}$) and 1-repetition max (1 RM) strength parameters for the Back Squat and Bench Press and Standing Shoulder Press.

Prior to testing, each participant's hydration status was tested using a urine refractometer (Atago Co., Tokyo, Japan). Participants with urine specific gravity (USG) of < 1.020 were permitted to complete VO$_{2max}$ testing. Participants with USG ≥ 1.020 were considered dehydrated, asked to consume fluids and return for testing when proper hydration status achieved. Following a 5 minute warm up on a treadmill at a comfortable walking speed, participants completed a Bruce protocol test to estimate maximal oxygen consumption. The Bruce protocol is arguably the most commonly utilized AE capacity assessment test and has been found to estimate VO$_{2max}$ in a comparable manner to other maximal oxygen consumption assessment techniques (19). Research findings have concluded that AE capacity testing protocols should resemble an individual's current training status or sport (13). Considering that the inclusion criteria protocol for this study   allowed for considerably low aerobic fitness in eligible participants, this walking protocol was deemed appropriate for this population. Exercise heart rates were recoded for each stage. Estimated VO$_{2max}$ values were calculated utilizing the following formula for VO$_{2max}$ estimation for women: VO$_{2max}$ (ml$\cdot$kg$^{-1}\cdot$min^{-1}) $= 4.38 \times$ T - 3.9 where T represents the total time completed, expressed in minutes and fractions of a minute.

Following preliminary testing, participants were randomized into one of two experimental groups: concurrent resistance with no incline HIIT sprints (CSIT0) and concurrent resistance with 6% incline HIIT sprints (CSIT6). Randomization was completed in a matched pairs design based on baseline VO_{2max} values. Baseline descriptive data can be found on Table 1.

Experimental Intervention

This HIIT-based concurrent exercise training study lasted for 12 weeks, with exercise training sessions taking place three days per week on a Monday, Wednesday and Friday Schedule. Two protocols, an undulating periodization RET and SIT protocols were completed during each session in alternation order to avoid any potential order effects. Prior to starting each training session, participants completed a general warm-up which included dynamic body-weight exercises, mobility work and active stretching. After each session, a cool down consisting of abdominal exercises and flexibility exercises was performed. Participants were under close supervision by qualified research staff for the entirety of the concurrent training program to ensure proper form and safety and were asked to refrain from adding any physical activity outside their normal routines during the course of the study. All training sessions were held in the Exercise Performance laboratory at Auburn University's School of Kinesiology. Participants attended three separate orientation sessions during which they were familiarized with treadmill protocol and correct weight lifting techniques for lifts such as back squat, standing shoulder press, chest press and bent over row. One RM pre training values were recorded for the back squat, chest press and standing shoulder press. Maximal muscular strength values were extrapolated from submaximal 3 repetition testing for each lift using the

Wathen formula. Post training measures of variables of interest were reassessed following the completion of the training program.

High Intensity Sprint Interval Training (SIT) Protocol:

The design of the SIT protocol was chosen to maximize important adaptive responses associated with HIIT in a timely manner. Participants were divided into two experimental groups; concurrent training with 0% incline SIT (CSIT0) or 6% incline SIT (CSIT6). Experimental group assignment followed a matched pairs design based on baseline VO_{2max} values. A three minute walking warm-up at 3.0 MPH preceded HIIT sprints. Each group completed the SIT treadmill protocol consisted of 40 seconds of high intensity running sprints followed by a 20 second long passive recovery performed at a speed and/or incline to induce CV responses of 95% of each participant's age predicted maximal heart rate, with both groups completing equal workloads. Maximal HR for each participant was declared as either their agepredicted maximal HR or the highest HR achieved during the maximal Bruce treadmill test, whichever higher. During the first 6 weeks of the study, participants completed 2 sets of three 40-second sprints separated by a 1-minute passive recovery in between sets. An additional set of 3 sprints were introduced on week 7 until the completion of the study. Sprint speed was adjusted as needed to continuously reach target HRs, thereby controlling for CV training adaptations. Upon the completion of all sets, a 3-minute walking cool down at a speed of 3 MPH culminated this protocol.

Undulating periodization resistance training protocol

A periodization resistance exercise training model was chosen in order to optimize the principle of overload, imposing stress to the neuromuscular system with varying stimuli. In

undulating periodization, intensity and volume are altered frequently with the goal obtaining

strength gains (21). Furthermore, Periodization models have been found to effectively maximize

the stress/recovery relationship while improving both muscular strength and endurance (22).

The undulating protocol chosen for this study was composed of two individual protocols,

workouts

"A" and "B" (Table 2) with three individual loading and repetition phases (Table 3). The

muscular endurance phase encompassed 3 sets of 10 repetitions at 65%, 70% and 75% of each

participant's 1RM for the Back Squat and Bench Press whereas the strength phase was

composed of 3 sets of 6 repetitions at 75%-80%-85% of calculated 1 RM. The muscular

hypertrophy phase was comprised of 3 sets of 8 repetitions at 75%-80%-85% of calculated 1

RM for each of the lifts respectively (Table 4). All training sets were proceeded by a warm-up

set or 5 reps at 50% of 1 RM. One RM values were extrapolated from submaximal 3 repetition

testing for the back squat and bench press using the Wathen formula, which has been found to

be a valid calculation for the prediction of maximal strength for this age group (14). Training

protocols A and B were performed on alternate training days throughout the study such that

each training scheme was completed 3 times every two weeks, with the number of repetitions

and load being altered every third training session.

Post Testing

Reassessment of exercise-training induced adaptations was conducted immediately

following the completion of this 12-week exercise training intervention. Post testing was

comprised of repeated measures of all physiological variables were obtained.

Statistical Analysis

The effects of training on dependent variables (VO_{2max}, T_{max}, HR_{max}, speed) were analyzed using a repeated-measures analysis of Variance (ANOVA) with one between- subject factor (Experimental group, with 2 levels CSIT0 and CSIT6) and one within-subjects factor (time, with 2 levels, pre and post). Experimental group by time interactions and simple main effects were analyzed. Standard statistical methods were used for the calculation of means, standard deviations (SD). Descriptive statistics are presented as mean $\pm$ SD. The significance level for this study was set at $P < 0.05$. Statistical analysis was completed using SPSS.

RESULTS

A total of 53 women ages 40-64 completed the 12 week study. Fourteen participants withdrew from the study due to inability to attend the training sessions, personal issues and injuries unrelated to the study. Pre-intervention, no significant differences were observed between the groups with respect to measures of height, mass, and body composition ($P < 0.5$).

Aerobic Capacity Parameters

Significant improvements in VO_{2max} were observed between pre and post training intervention for both CSIT0 (VO_{2max} 2.11 ± 0.390 to 2.29 ± 0.382 L·min^{-1}, $P = 0.006$) and CSIT6 (VO_{2max} 2.03 ± 0.382 to 2.09 ± 0.561 L·min$^-$1, $P = 0.006$). Significant differences were also detected between pre and post T_{max} (CSIT0 T_{max}: Pre = 490.5 ± 102.3s, Post = 542.7 ± 81.5s, CSIT6 T_{max}: Pre = 503.2 ± 75.4s, Post = 541.8 ± 77.0s; $P < 0.0001$) and pre and post V_{max} (CSIT0 V_{max}: Pre = 5.1 ± 0.92 MPH, Post 5.9 ± 0.90 MPH, CSIT6 V_{max}: Pre = 4.3 ± 0.68 MPH, Post 4.9 ± 0.64 MPH, $P < 0.0001$) for both experimental groups, No significant between-group interactions were detected for VO_{2max} ($P = 0.173$), Tmax ($P = 0.431$) and Vmax ($P = 0.400$).

DISCUSSION

The main findings of this study were that following 12 weeks of a high intensity incline (6%) or level-grade (0%) SIT-based CET program, physiological adaptations occurred that lead to significant improvements in AE capacity parameters in aging women whose physical activity was initially recreational in nature and failed to meet recommendations. The improvements in AE capacity were observed in both experimental groups in the following measures: absolute maximal oxygen consumption (VO_{2max} in $L \cdot min^{-1}$), maximal time (T_{max}) on the treadmill during Bruce Protocol assessment of VO_{2max} expressed in seconds (s) and maximal velocity (V_{max}) required to induce CV responses of 95% of age-predicted maximal heart rate (HR_{max}) during SIT, in miles per hour (MPH). While each of these changes reached statistical significance (p= 0.00) in both level-grade (CSIT0) and incline (CSIT6) experimental groups, between group interactions of significance were not detected. This paper contributes to a growing body of literature that supports the notion that while any type of lifelong exercise training supports proper AE capacity and helps maintain functional independence into late life, those performed at high intensities effectively produce significant adaptive responses in a safe and time efficient manner. The lack of between group interactions indicates that both incline and level-grade SIT produced comparable adaptive responses for all AE capacity variables when participants exercised at similar maximal heart rate values of 95%. These results differ from previous claims that superior adaptive responses occur from INC-based training when compared to level-grade. In fact, while statistically insignificant, VO_{2max} improvements in the CSIT0 group were higher in average

(8.5%) than those resulting from CSIT6 (3.0%). A similar trend was observed for both T_{max} (CSIT0 15.7% versus CSIT6 14.0%) and V_{max} (CSIT0 10.8% versus CSIT6 7.7%). Therefore, our findings contradict the unfounded but popular claims suggesting greater physiological advances, specifically in regards to AE capacity, from uphill training.

In women, the negative relationship between levels of PA and age (28) indicates that older women are particularly afflicted by a growing risk for CV impairments and related health and functional disability- consequences of the aging process which are aggravated by insufficient physical activity levels. Thus, a time-efficient, all-inclusive exercise training protocol addressing age and inactivity related physiological declines represents an attractive approach for health promotion and functional independence for aging populations. The primary adaptive response resulting from this modified concurrent SIT and RET program was the significant time interaction for AE capacity parameters including maximal VO_{2max}, T_{max} and V_{max}, suggesting substantial CV adaptations from the intervention without significant contributions from the added vertical incline challenge. This exercise intervention is therefore an ideal approach to prevent the expected debilities associated with aging and insufficient PA in recreationally active females ages 40 through 64.

Aerobic Capacity (VO$_{2max}$)

The reductions in VO_{2max} that occur due to age contribute to a decrease in functional capacity for activities of daily living. While aging is a maturational and irrevocable process, modern physiological research has challenged the despair of age-related physical decline by suggesting that health and physical deteriorations are at least in part, a result of physical inactivity and physiological disuse. The inverse relationship between women's age and PA levels (28), indicates that the age-related declines women experience are, at least in part, the

result of insufficient PA. Moreover, it has been found that women who partake in regular exercise exhibit significantly greater absolute levels of maximal aerobic capacity than do their sedentary counterparts, which translates into higher functional capacity throughout the aging process (9).

Our investigation sought to determine whether 12 weeks of high intensity incline or level-grade SIT-based CET would reduce the AE capacity declines related to physical inactivity (PI) and aging in recreationally active women ages 40-64. The results from our study revealed significant improvements in post VO_{2max} values in both the CSIT0 and CSIT 6 experimental groups indicating that each protocol produced sufficient challenges to the CV system to induce adaptive responses. Peak aerobic capacity (VO_{2peak}) is considered the single best predictor of cardiac and all-cause deaths, and is observed to decline severely in women as they age starting during the menopausal transition (20). Thus, increases in post training VO_{2max} values may decrease the risk for premature death in a population experiencing an age-related decline in physiological processes and anatomical structures. The improvements in VO_{2max} provide additional confirmation of the effectiveness of HIIT-based interventions at enhancing aerobic capacity (3, 4, 10, 24). Our findings are also in agreeance with our previous SIT-based CET interventions which produced VO_{2max} improvements in young, sedentary women (15); confirming that the high intensity nature of our intervention design represents a successful method to improve AE parameters.

High Intensity Interval Training and Aerobic Capacity Parameters

Evidence from previous studies advocates that high-intensity exercise training may yield physiological adaptations and AE benefits equivalent or superior to other training programs of lesser intensities in a shorter amount of time (3, 24). While the large majority of these studies

employed cycling-based protocols, the exercise intensities in these studies were comparable to those used in the treadmill SIT protocol chosen for our study. Researching muscle oxidative potential and AE capacity, Burgomaster et al. reported a near two-fold increase in T_{max} at 80% of VO_{2max} following a total of only 6 sessions of 30-second Wingate-based SIT in a 2-week period (4). Utilizing the same protocol, this research group compared metabolic adaptations resulting from their SIT-based intervention to those resulting from traditional, moderate intensity endurance training approach. Despite a difference in exercise volume of close to 90%, equivalent metabolic adaptations indicative of enhanced muscle oxidative capacity resulted from both interventions indicating equivalent adaptive responses can be obtained in a significantly more time-efficient manner with exercise of near maximal intensities. These studies also detected changes in endurance capacity (4) and VO_{2max} (3). Our SIT protocol was comprised of sets of two then three, 40-second sprints running sprints at specific intensities to incite 95% of each participant's age-predicted maximal heart rate. As CV adaptations occurred, sprint speed was increased to retain the target heart rates, thus maintaining the CV challenge. After the completion of our intervention, participants in both experimental groups experienced increases in the time they were able to sustain near-maximal intensity exercise during a Bruce protocol assessment of VO_{2max} (T_{max}), signifying improvements in muscular and cardiorespiratory endurance. In turn, these improvements translate to enhancements in functional capacity, hence a greater ability to maintain mobility and independence during late adulthood. Furthermore, significant increases in V_{max} or the maximal velocity required to obtain 95% of each participant's age-predicted HR_{max} were detected in both groups. These improvements are indicative of adaptations from the CV and respiratory systems indicating

improved AE functional capacity and potentially, significant health benefits associated with our intervention.

Despite the advantages associated with high intensity exercise training, safety concerns have been raised when utilizing this approach for older populations or those at risk for CV events. Contradicting this notion is evidence of HIIT-based interventions which have been safely completed in at-risk populations. Rognomo et al. compared changes in peak AE capacity (VO_{2peak}) produced by HIIT to those resulting from moderate intensity exercise training (24) in stable coronary artery disease patients, and found that superior VO_{2peak} improvements were safely obtained from HIIT in diseased populations when compared to results from lower intensity exercise training. In view of this evidence and our findings, it can be inferred that exercise training programs of high intensity are well-tolerated and convey significant AE benefits in cohorts composed of older and low fitness individuals.

Incline-based exercise training

AE capacity adaptive responses to INC-based exercise training have been documented in trained males. A previous study by Houston and Thomson (11) found that after 6 weeks of uphill running performed concurrently with RET, endurance capacity improvements were observed despite no changes in VO_{2max} in endurance trained men. Significant improvements were detected in the following parameters: T_{max}, greater distance covered during a timed trial, resting adenosine triphosphate and increased final blood lactate values. In addition, participants in this study demonstrated significant muscular strength gains during 15 repetition maximum leg press training. This investigation however, did not compare these adaptations from those resulting from comparable level-grade protocols. In contrast with these findings, our intervention; while significantly longer in duration; lead to significant increases in VO_{2max}, V_{max}

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and T_{max} indicating adaptive responses of the CV and supportive systems. However, the lack of difference in the aerobic adaptive responses of both experimental groups questions the popular myth claiming superior adaptations from INC.

PRACTICAL APPLICATIONS

To the best of our knowledge, this is the first study to investigate differential responses to level grade versus incline SIT in inactive women ages 40-64. According to the ACSM, forty percent of this study's starting participants had baseline VO_{2max} values which fell under the "poor" to "fair" cardiorespiratory fitness categories depending on their specific age group (18). It can be assumed that these values will only continue to decline as a result of insufficient PA and age-related physiological changes. Unless a regular exercise training program is adopted, the declines in AE capacity may reach severely low levels below those required for daily baseline function in late life. While HIIT may signify an ideal approach to combat such declines, this population may not be able to safely perform sprints at high velocities. Furthermore, the age related decreased ability to recruit type II fibers required for high speed exercises may prevent aging individuals from acquiring the numerous benefits associated with HIIT. By including a vertical challenge into the SIT protocol, our intervention allowed for exercise intensities required to obtain the AE benefits associated with high intensity exercise to be obtained at lower velocities, therefore allowing our cohort to exercise at high intensities with a lowered risk for incidents. Furthermore, the resulting enhancements resulting from our intervention, regardless of the experimental condition, reflects the effectiveness of INC SIT-based CET to significantly improve AE capacity, and address the age-related functional declines. Considering that maximal aerobic capacity has been shown to be an independent risk factor for all-cause and CVD mortality (2), the CV adaptations resulting from our high intensity

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interval CET may reverse the women's risks for premature death observed in older individuals

(9) and represents a powerful strategy to ameliorate and/or prevent the declines in physiological

parameters commonly resulting from the inevitable process of aging.

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Manuscript I, Table 1.

	Monday	Wednesday	Friday
Week 1	Protocol "A"	Protocol "B"	Protocol "A"
Week 2	Protocol "B"	Protocol "A"	Protocol "B"

Table 1. Weekly resistance training protocol scheme

Manuscript I, Table 2.

Undulating Periodization Phase	Scheme
Muscular Conditioning/ Endurance Phase	3 sets of 10 repetitions 65%, 70%, 75% 1RM
Muscular Strength Phase	3 sets of 6 repetitions 75%-80%-85% 1RM
Muscular Hypertrophy Phase	3 sets of 8 repetitions 75%-80%-85% 1RM

Table 2. Undulating Periodization Schemes

Manuscript I, Table 3

	CSIT0	CSIT6
Anthropometric Data		
Age (yr)	51.9 ± 6.6	53.4 ± 7.6
Height (cm)	162.5 ± 5.6	161.5 ± 4.9
Mass (kg)	74.9 ± 16.9	70.0 ± 13.5
BMI	28.4 ± 5.8	26.2 ± 4.8
Body Fat %	40.6 ± 6.6	39.4 ± 6.4
Lean Mass (kg)	43.4 ± 6.7	40.4 ± 5.9
N	27	26

Table 3. Subject Characteristics. All values are presented as means ± standard deviations.

Manuscript I, Table 4

	CSIT0		CSIT6	
	Pre	**Post**	**Pre**	**Post**
Body Composition				
Body Weight (kg)	74.9 ± 16.9	74.3 ± 16.3	70.0 ± 13.5	69.9 ± 12.2
Body Fat %	40.6 ± 6.6	$39.5 \pm 6.7*$	39.4 ± 6.4	$38.6 \pm 5.95*$
Visceral Adipose Tissue (kg)	0.871 ± 0.797	$0.825 \pm 0.671*$	0.890 ± 0.757	$0.831 \pm 0.666 *$
Femoral Neck BMD (g/cm^2)	0.934 ± 0.114	0.938 ± 0.112	0.971 ± 0.144	0.970 ± 0.142
AP BMD (g/cm^2)	1.220 ± 0.161	1.240 ± 0.173	1.200 ± 0.160	1.210 ± 0.173
LBM (kg)	43.4 ± 6.7	42.4 ± 6.7	40.5 ± 5.9	41.3 ± 5.6
Muscular Strength				
1RM Back Squat (kg)	49.2 ± 19.2	$91.1 \pm 24.7*$	41.2 ± 15.9	$86.8 \pm 31.3*$
1 RM Bench Press (kg)	31.7 ± 9.2	$41.0 \pm 7.75*$	28.9 ± 7.7	$38.1 \pm 9.88*$

Table 4. Body composition and muscular strength data. All values are presented as means

standard deviations. *denotes significant differences between groups ($P < 0.05$)

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Manuscript I, Figure 1.

Figure 1. 1 RM back squat pre vs. post training. Values are reported as means ± SD. *Denotes significant differences from pre values (P < 0.05). No significant differences detected between training protocols.

Manuscript I Figure 2.
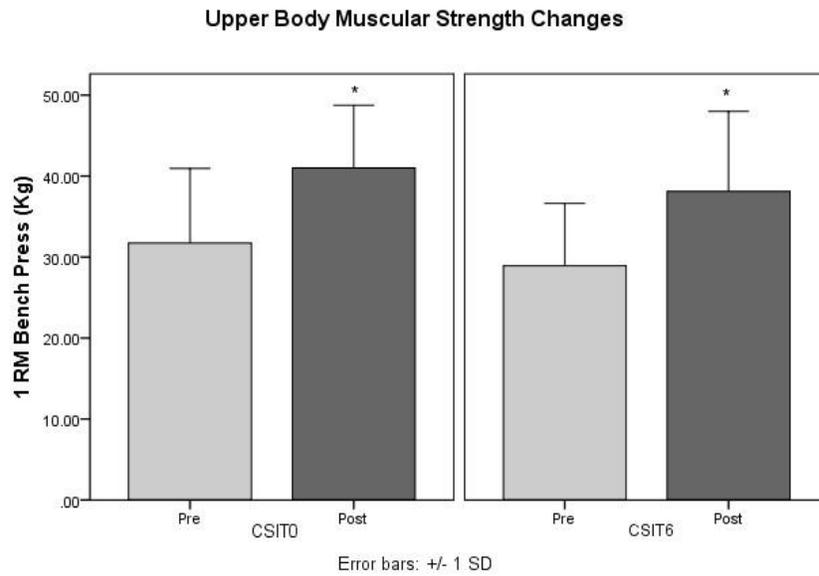
Figure 2. 1 RM bench press pre vs. post training. Values are reported as means ± SD. *Denotes statistically significantly changes were found from pre values (P < 0.05). No significant differences detected between training protocols.

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Manuscript II, Table 1

	CSIT0	CSIT6
Anthropometric Data		
Age (yr)	51.9 ± 6.6	53.4 ± 7.6
Height (cm)	162.5 ± 5.6	161.5 ± 4.9
Mass (kg)	74.9 ± 16.9	69.9 ± 13.5
BMI	28.4 ± 5.8	26.2 ± 4.8
Body Fat (%)	41.6 ± 6.2	39.8 ± 7.2
Lean Mass (kg)	42.2 ± 6.5	40.4 ± 5.8
N	27	26
Aerobic Measures		
VO_{2max} (L/min)	2.11 ± 0.39	2.03 ± 0.38
V_{max} (MPH)	5.1 ± 0.92	4.3 ± 0.68
T_{max} (s)	490 ± 102.3	503 ± 75.4

Table 1. Subject Characteristics. All values are presented as means $\pm$ standard deviations.
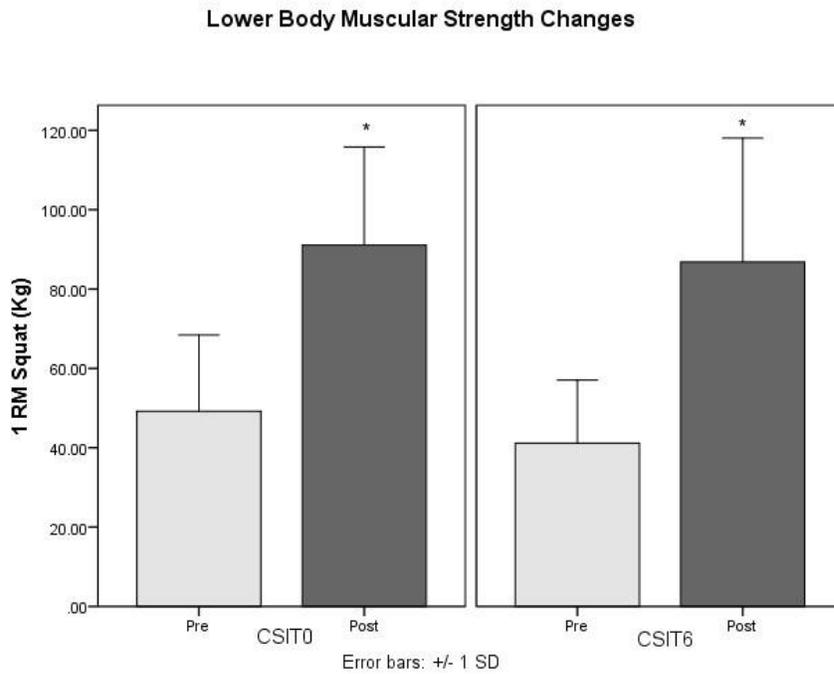*Denotes significant differences between groups ($p \leq 0.05$)

Manuscript II, Table 2

Protocol A	Protocol B
• Back Squat	• Squat Jumps
• Bent Over Row	• Weighed Lunges
• Bench Press	• Standing Shoulder Press
	• Back Extensions

Table 2. Resistance Training Protocols

Manuscript II, Table 3

	Monday	**Wednesday**	**Friday**
Week 1	Protocol "A"	Protocol "B"	Protocol "A"
Week 2	Protocol "B"	Protocol "A"	Protocol "B"

Table 3. Weekly resistance training protocol scheme

Manuscript II, Table 4.

Undulating Periodization Phase	Scheme
Muscular Conditioning/ Endurance Phase	3 sets of 10 repetitions 65%, 70%, 75% 1RM
Muscular Strength Phase	3 sets of 6 repetitions 75%-80%-85% 1RM
Muscular Hypertrophy Phase	3 sets of 8 repetitions 75%-80%-85% 1RM

Table 4. Undulating Periodization Schemes

Manuscript II, Table 5

CSIT0	PRE	POST
Aerobic Measures		
VO_{2max} (L/min)	2.11 ± 0.39	2.29 ± 0.37 *
V_{max} (MPH)	5.1 ± 0.92	5.9 ± 0.90 *
T_{max} (s)	490 ± 102.3	542.7 ± 81.5 *

CSIT6	PRE	POST
Aerobic Measures		
VO_{2max} (L/min)	2.03 ± 0.38	2.09 ± 0.56 *
V_{max} (MPH)	4.3 ± 0.68	4.9 ± 0.64 *
T_{max} (s)	503 ± 75.4	541.9 ± 77.0 *

Table 5. Pre and post intervention Aerobic Capacity measures. All values are presented as means $\pm$ standard deviations.*Denotes significant differences from pre training values ($p \leq 0.05$)

Manuscript II, Figure 1
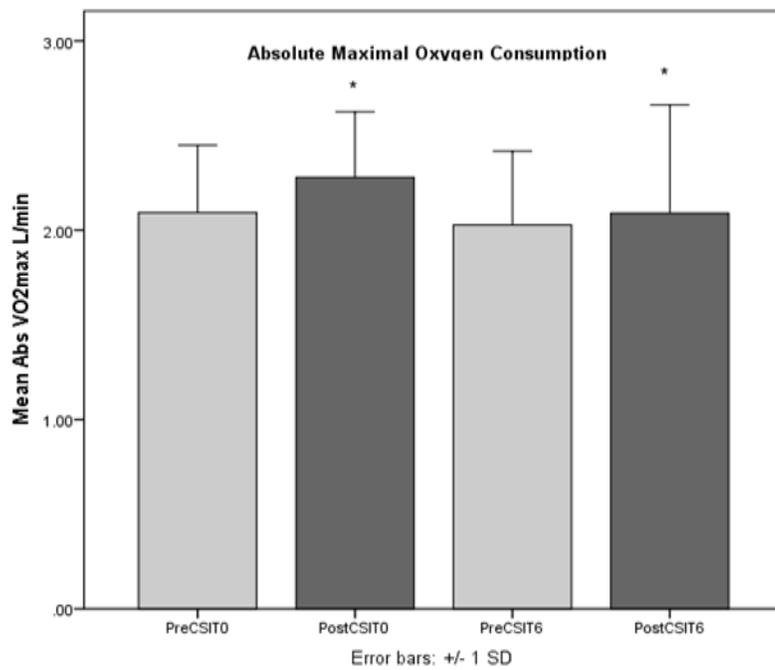
Graph 1. Pre and post intervention Absolute Maximal Aerobic Capacity (VO_{2max}) in L/min. All values are presented as means ± standard deviations.

*Denotes significant differences from pre training values ($p \leq 0.05$)

Manuscript II, Figure 2

Graph 2. Pre and post intervention Time to Exhaustion (T_{max}) in seconds. All values are presented as means ± standard deviations.

*Denotes significant differences from pre training values ($p \leq 0.05$)

Manuscript II, Figure 3
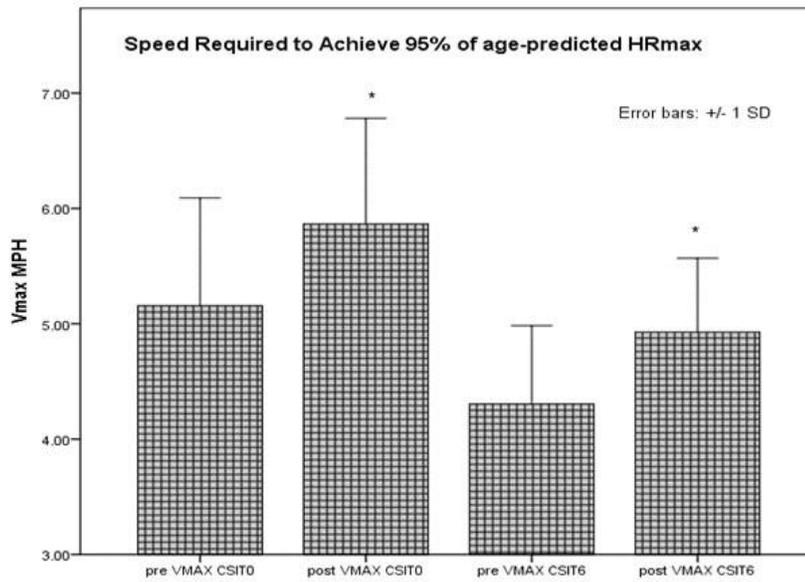
Graph 3. Pre and post intervention Speed required to achieve 95% of age predicted HR_{max} (V_{max}) in MPH. All values are presented as means ± standard deviations. *Denotes significant differences from pre training values ($p \leq 0.05$)

Appendix A
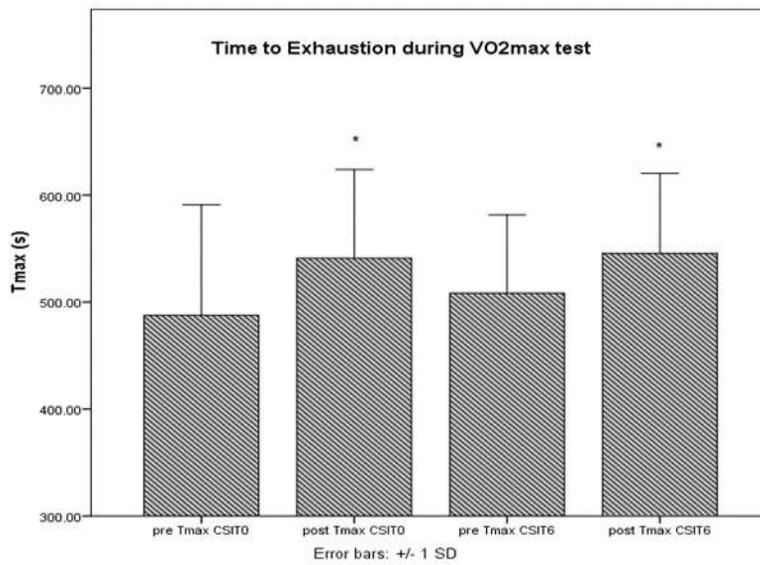
RECENT TRAINING HISTORY QUESTIONNAIRE

Subject code number:_____ Date:_____

Please answer these questions regarding your recent training level. Interval training is defined as alternating periods of high intensity or maximal effort alternated with periods of low intensity of complete recovery.

1.   On average, how many days per week do you perform resistance exercise? How many minutes on average for each session?

_____

2.   On average, how many days per week do you perform endurance exercise? How many minutes on average for each session?

_____ 3.

Have you made any changes to your exercise habits in the last 3 months?

_____

4. Did you do any interval training during this time? If yes, please describe.

_____

_ _____

_ _____

_ _____

Participants Signature_____

Recruitment Script

"Effect of high intensity exercise training on physiological, psychosocial and exercise adherence parameters in women"

Purpose:
You are invited to participate in a training research study that will investigate physiological adaptations (aerobic capacity, body composition, muscle mass, fat mass, strength and power), psychosocial changes (how you feel about your training and exercise), and issues pertaining to exercise adherence with this training regimen. To conduct this experiment we are looking to recruit healthy females who are not currently exercising more than 3 days per week to participate in a 12 week training study. There will be follow up assessments on weeks 19 and 26.

Participant Qualifications:

- Female
- Age 40 - 64
- Health (as determined by screening document)
- Do not current engage in vigorous activity more than 3 days per week (running, swimming, weight training, etc.)

Requirements:
If you decide to participate you will be asked to read and sign both an informed consent and Physical Activity Readiness Questionnaire (PAR-Q) to determine if you are healthy enough to begin a new training program. Initial testing will include: body composition measurements using an iDEXA scan, resting blood pressure, a VO2 max test performed while running on a treadmill, and one repetition max for the standing press, back squat, and bench press. Additionally, you will attend performance testing protocol familiarization which will include 3 visits to the lab to learn all testing procedures. This initial familiarization and testing will take 2 weeks.

Benefits:
You will receive free exercise training (i.e. strength training, cardiovascular) for 13 weeks and follow up testing for two additional weeks. In addition you will receive detailed feedback on your training and nutritional intake, as well as, all of your results including a full body fat analysis. Previous benefits from this study have shown an increase in lean body mass.

After initial testing you will begin 10 weeks of performing concurrent strength training and sprint interval training on a treadmill. Training will occur 3 days / week and time commitment will not exceed 1 hour 15 minutes per day.
YOUR PARTICIPATION IS COMPLETELY VOLUNTARY!

If you choose to participate, you have the right to stop at any time. Your choice of whether or not to participate in this study will in no way effect your relationship with the researchers or the Department of Kinesiology. Recorded data will be available only by participant number.

Contact Information: Please contact Danielle Wadsworth via e-mail at wadswdd@auburn.edu or Lorena Salom (lps0005@auburn.edu) or telephone at 334-844-1836 for more information.

Appendix C

PAR Q Medical Questionnaire*

Please read each question carefully and answer honestly. If you do not understand the question, please ask the investigator for clarification. Check the appropriate answer.

No   Yes

_____ _____ 1. Are you under 19 years old or over the age of 39 years?

_____ _____ 2. Do you presently smoke or have been a regular smoker?

_____ _____ 3. Has your doctor ever said you have heart trouble?

_____ _____ 4. Do you have a family history of early cardiovascular death before the age of 50?

_____ _____ 5. Have you ever had a heart murmur, rheumatic fever or respiratory problems?

_____ _____ 6. Have you ever been told that you have a fast resting heart rate?

_____ _____ 7. Have you ever been told by your doctor or nurse that your blood pressure is too high?

_____ _____ 8. Have you ever been told that your cholesterol is too high?

_____ _____ 9. Have you been told that you have a kidney disorder?

_____ _____ 10. Have you been told that you have diabetes or that your blood sugar is too high?

_____ _____ 11. Have you been told that your electrocardiogram (EKG), 12 lead EKG or stress test is not normal?

_____ _____ 12. Do you have any rashes or reactions that result from hot or cold exposures (hot or cold uticaria)?

_____ _____ 13. Have you been hospitalized in the past year?

_____ _____ 14. Are you taking prescription medicine?
        If so, what? _____ _

Note that taking certain medications may cause you to be excluded from participation in this study including those that cause increases in heart rate, or other drugs that may, increase the risk of participation
.

_____ _____ 15. Do you have any orthopedic issues that would interfere with your participation in this study?

_____ _____ 16. Do you have any reason to believe that your participation in this investigative effort may put your health or well being at risk? If so, please state reason.

Signature of subject _____ Date _____ _

AUBURN UNIVERSITY

COLLEGE OF EDUCATION

Informed Consent for a Research Study Entitled

"Effect of high intensity exercise training on physiological, psychosocial and exercise adherence parameters in women"

Project Overview: You are invited to participate in a research study that will examine the effect of a concurrent training program including aerobic and strength training, on power outputs and exercise adherence changes in recreationally active females. We are recruiting participants to complete a 13 week study. Participants will participate in a concurrent strength training and sprint high intensity interval training (HIIT). We will also be investigating the exercise adherence and behaviors related to the participation in exercise training regimen.

Purpose: The purpose of this investigation is to examine aerobic, strength, power outputs and exercise adherence changes that occur following each training intervention.

Participation Requirements: To be eligible, you must be:

1. Female participant between 40 and 64 years of age
2. Maximal oxygen consumption levels above 20 ml/kg/min as determined by preliminary VO2 max testing.
3. Low risk for medical complications (as determined by physical activity readiness questionnaire (PARQ)).
4. Currently engaging in no more than three days per week of moderate strength and/or endurance training (as determined by recent activity questionnaire).
5. Currently not taking any medications that will increase the risk of participation, or interfere with testing variables. Note that taking certain medications may cause you to be excluded from participation in this study including those that cause increases in heart rate, or other drugs that may increase the risk of participation

You must meet all of the requirements to be eligible for participation in this study

Time commitment for participation in this study will be approximately 40 hours. Lab training time will last 13 weeks with follow-up on weeks 19 and 26.

Day 1: On the first visit to the lab, you will complete the PARQ Questionnaire, complete the current activity questionnaire, and read and sign the University-approved informed consent form. Drs Danielle Wadsworth, Jim McDonald, David D. Pascoe or Graduate student Lorena Salom will be present for all informed consent briefings. If ineligible for participation for any reason (participation requirements or PAR-Q,) all forms will be returned to the subject and no record will be kept by the researchers. Descriptive data will be obtained (age, height, weight, blood pressure, cheek swab and iDEXA (body composition)). Hydration level will be assessed using a urine refractometer from a urine sample provided. If adequately hydrated, you will then become familiar with walking/running on the Woodway treadmill. You will then complete a VO2 max test, an incremental treadmill walking/running test designed to determine your maximal oxygen uptake. We will monitor you closely and ensure that you complete a thorough cool-down by walking for several minutes at a comfortable pace.

The total time for the exercise testing will be approximately twenty minutes (including a warm-up and cool down) while descriptive data will not take more than 40 minutes, making total time commitment for the entire visit approximately one hour.

Day 2 – Day 7: Over this 5 day period, you will return to the lab on three separate occasions to become familiar with testing procedures including the back squat, standing press, bench press, and treadmill walking/running protocol as needed. Additional familiarization opportunities will be provided as needed. On the last familiarization day you will perform supervised one repetition max (1RM) tests for the back squat, standing press and bench press. Total time commitment for each visit is 45 minutes.
Detailed descriptions of each test can be found at the end of this document. Participants will be given a dietary log on Monday to record throughout the week. Logs will be collected on the following Monday by the researchers. You will also be asked to wear an accelerometer and a GPS unit around your waist. These measures allow us to determine how much exercise you do outside of the lab and in what contexts (i.e. outside, gym etc.) you complete additional exercise in.

Monday: Practice for back squat, standing press, bench press
Wednesday: Practice training protocol to include treadmill walking/running and resistance training
Friday: 1 RM testing for back squat, standing press, bench press
Time commitment for the week = 3.5 hours after testing you will begin your training protocol. The exercise protocol is described below:

Strength Training Protocol -
   • General warm-up will be completed before each session
   • Two alternating training days will be used
   • Sets, reps, and intensity will be altered after every two training sessions
   • Each program will be individualized based on you testing variables
   • Training will occur at the same time each day and will not exceed 45 minutes
   • All training will be overseen by a certified strength and conditioning coach
   • Time commitment = 2.0 hours/week

Sprint HIIT Protocol -
   • 3 minute warm-up will be completed consisting of a walk/jog at 50% your VO2 max

- Participants will be allowed to stretch as needed prior to intervals

- HIIT training will consist of intervals (3 intervals for the first two weeks building to 9 intervals for the last 6 weeks of the study) each interval lasting 40 seconds walking/running, with 20 seconds passive recovery
- 3 minute cool-down will be completed at 50% of VO2 max
- Speed of the walk/run will be individualized and based on testing outcomes
- Training will occur at the same time each day and will not exceed 20 minutes
- Time commitment = 1 hour / week

Training Weeks 2 – 12
- Training will take place three days per week: Monday, Wednesday, and Friday
- Participants will be asked to consume at least 1 pint of water before reporting for the workout □ Time commitment 2.5 – 3.5 hours per week.
- You will have blood taken prior to the beginning of your first exercise protocol. A total of 36 ml (2.4 tablespoons) will be drawn. Blood collection will be repeated again on weeks 6 and 12 of the study, for a total of 108 ml (7.2 tablespoons). The blood will be taken from your arm. The risks of taking blood include pain, a bruise at the point where the blood is taken, redness and swelling of the vein and infection, and a rare risk of fainting.

Post Testing – Week 13 – will be a retest of all variables examined in week 1. Dietary logs will be returned to participants on Friday of week 12 and you will be asked to replicate dietary intake from the first week as closely as possible. Testing schedule is found below:

Monday: 1 RM testing for back squat and standing press
Tuesday: Collect anthropometric data
Wednesday: VO2 Max
Friday: Make-up tests

Time commitment for the week = 3.5 hours
Total time commitment for lab participation = 12 weeks – approximately 40 hours

Adherence to protocol -Weeks 14-19 – Upon the conclusion of your lab training you may receive reinforcement messages to help you maintain your activity levels. The messages will be sent as texts. You may receive up to three messages each week. You are responsible for any costs occurred via text.
Retention measures – Weeks 19 and 36 – There will be follow-up testing, where you will be asked to you to return to the lab and complete the same measures as during week 1 testing. Time commitment for the week = 3.5 hours

Test Descriptions:
VO2 Max – Perform incremental treadmill test with O2 consumption monitored via a True Max Metabolic Testing System.
All 1 RM assessments will be obtained in no more than 4 attempts
1 RM Back Squat – Participants will warm-up; followed by a set of 10 squats with an empty bar. An additional warm-up sets; 5 reps with 50% of predicted 1 RM and 2 sets of 3 reps with 70% of 1RM will be performed.
1 RM Standing Press - Participants will warm-up; followed by a set of 5 standing presses with an empty bar. An additional warm-up set; 5 reps with 50% of predicted 1 RM and 2 sets of 3 reps with 70% of 1RM will be performed.

1 RM Bench Press – Participants will warm-up; followed by a set of 5 standing presses with an empty bar. An additional warm-up set; 5 reps with 50% of predicted 1 RM and 2 sets of 3 reps with 70% of 1RM will be performed.

Potential Risks:
1. While performing any exercise there is a chance of muscle strains, sprains, pulls, and even death. The American College of Sports Medicine estimates the risk of sudden cardiac death 1 per 36.5 million hours of exertion.
2. Due to the high intensity nature of some of the exercises, you may feel nauseous and/or lightheaded after completing the intervals.
3. With any blood collection procedure there is a risk of infection, bleeding, bruising, irritation at injection site, and/or fainting.

"Note" It is important for you to realize that you are responsible for any costs incurred in the event of an injury.

Precautions:
1. Although the training for this trial is of higher intensity, it is of short duration and at a comfortable environmental temperature and humidity level. Heart rate will be recorded throughout the trial. We will also collect data on your daily activity using a wrist accelerometer and a GPS unit to monitor free living exercise behavior.
2. We have additionally employed the use of a modified PARQ to assist in eliminating participants that have potential medical or orthopedic identified risks. During the trials you will always be accompanied by researchers who maintain current CPR Certifications.
3. After each exercise bout you will be monitored and be given a chance to cool-down.
4. Investigators participating in blood data collection (David Pascoe, Jim McDonald, and Lorena Salom) have completed NIH approved phlebotomy training. Only new, sterile blood-gathering equipment and aseptic techniques will be utilized throughout all data collection and analysis processes.
5. The training program was designed by Dr. Rich Laird, PhD and Certified Strength and Conditioning Coach. It has been used safely and effectively in previous Auburn Studies. Proper lifting technique, volume and intensity manipulation, and spotting will be employed to decrease the risk of injury.
6. Should an emergency arise, we will call 911 and follow our emergency action plan. You are responsible for any cost associated with medical treatment.

Benefits: You will receive 12 weeks of organized and supervised training, along with performance assessments including body composition, VO2 max, 1 RM squat, 1 RM bench, isometric squat force and genotype information.

Your participation is completely voluntary. If you change your mind about participating, you can withdraw at any time during the study. If you choose to withdraw, you can request to have your data withdrawn. Your decision about whether or not to participate or to stop participating will not jeopardize your future relations with Auburn University, the S of Kinesiology, or any of the researchers. Your privacy will be protected. Any information obtained in connection with this study will remain anonymous.

If you have any questions, we invite you to ask us now. If you have questions later, you can contact Danielle D. Wadsworth (wadswdd@auburn.edu), Lorena P. Salom (lps0005@auburn.edu), James R. McDonald (jrm0013@auburn.edu) or David Pascoe (pascodd@auburn.edu), or call 334-844-1836. You will be provided with a copy of this document for your records.

For more information regarding your rights as a research participant, you may contact the Auburn University Office of Human Subjects Research or the Institutional Review Board phone number (334) 844-5966 or email at hsubjec@auburn.edu or IRBChair@auburn.edu.

HAVING READ THE INFORMTION PROVIDED, YOU MUST DECIDE WHETHER OR NOT YOU WISH TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATES YOUR WILLINGNESS TO PARTICIPATE.

Participant's signature   Printed Name   Date
_____   _____   _____

Investigator obtaining consent   Printed Name   Date
_____   _____   _____

Co-Investigator   Printed Name   Date
_____   _____   _____