ASSESSMENT OF 4 WEEKS OF P90X® TRAINING ON MUSCULAR STRENGTH AND ENDURANCE, ANAEROBIC POWER, AND BODY COMPOSITION

by
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ABSTRACT

The purpose of this study was to investigate the effect of a 4 week P90x® training intervention on markers of physical fitness: upper body strength (US), lower body strength (LS), upper body endurance (UE), lower body endurance (LE), mean anaerobic power (MP), and body composition (%BF). College-aged adults (*N* = 13) were tested before and after the 4 week training intervention with a bench press and half squat exercises, Wingate anaerobic cycling test, and 7-site skinfolds. A one-way repeated measures multivariate analysis of variance (MANOVA) documented a relationship between the training intervention and changes in the dependent variables F (1, 5) = 7.37, p = .022, η^2 = .898. There were significant improvements observed in US, p = .036; UE p = .003; LS, p = <.001; LE, p = .005; and %BF, p = .004. No significant change was observed in MP, F (1, 10) = 2.35, p = .16, η^2 = .19. These findings demonstrate that the P90x® training program can be an effective tool for improving measures of physical fitness. Due to its effectiveness, one-time purchase cost, convenience of home-use, and video-led training, P90x® could be a viable method for addressing perceived barriers of exercise such as lack of time, cost, lack of an exercise partner.

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CHAPTER I

INTRODUCTION

The need for physical activity and exercise in healthy adults, as well as other populations, has been well established (Haskell et al., 2007). Nearly half of the adult population 18 years of age and older in the United States has been reported as meeting neither the minimum recommendations for aerobic activity nor the minimum recommendations for muscle strengthening activity (National Center for Health Statistics, 2012). There is no apparent singular cause for the low percentage of U.S. adults who engage in physical activity. However, there are several potential barriers and perceived barriers to exercise that may dissuade persons from engaging in exercise or physical activity and, therefore, contributing to the low levels of exercise and physical activity reported.

Potentially a large factor influencing the lack of activity reported in the adult population in the United States is the advancement of technology and streamlining of what were once labor-intensive jobs. The advancement of modern technology has reduced the rate of energy expenditure (EE) during daily activities and work and this reduced rate of activity is further compounded by incentivizing typically more sedentary jobs through higher pay (Ferreira et al., 2009; Haskell et al., 2007). Exercising in the home could eliminate or significantly reduce several barriers to exercise and physical activity: the need for exercise facilities; time required for exercise; and financial costs.

Home exercise programs present a solution to some barriers or perceived barriers to exercise and physical activity that persons may experience. Time commitments could be decreased simply through the convenience of being able to exercise at home rather than having to allot additional time for travelling to and from an external facility. Rather than paying ongoing gym membership fees, trainer fees, and transportation costs to and from facilities, home-based exercise programs typically involve a one-time purchase of an entire program. While the initial cost can be large, the long-term cost compared to traditional facilities and services could be particularly appealing to those who perceive financial cost as a barrier to exercise. Lack of an exercise partner as a perceived barrier could also be addressed by home-exercise programs because these video-based programs provide motivation in the form of a coach leading the program with other participants in the video. P90x® is a highly marketed and popular home-based exercise program.

P90x® is a DVD-based training program designed to be performed in the home with minimal equipment. However, there is a lack of peer-reviewed research examining the effectiveness of this program. An investigation of the P90x® program in an unpublished thesis examined the oxygen (O_2) costs of four of the P90x® workouts (Woldt, 2011). Aside from Woldt's study, there is no available literature examining the O_2 costs or any other physiological adaptations resulting from the P90x program.

The P90x® DVD-based home exercise programs consists of exercise programming that is designed to be of a high intensity with frequently varying modes of exercise with short rest periods. P90x® uses principles of circuit resistance training (CRT) and high intensity interval training (HIIT) to elicit the high intensity and constantly varied exercises that the program is widely known for. While there is an apparent lack of research directly into P90x®, there is a wealth of research into the training principles, CRT and HIIT, on which the training program is based. Circuit resistance training and HIIT have been shown to provide benefits similar to traditional training methods while requiring a typically shorter training time requirement (Alcarez, Perez-Gomez, Chavarrias, & Blazevich, 2011; Gotshalk, Berger, & Kraemer, 2004). P90x® utilizes resistance bands, dumbbells, pull-up bars, and sometimes other devices as a means of increasing resistance.

The P90x® exercise program is marketed as muscle building and fat loss program. This program is built on principles of CRT and HIIT, which are well researched and known to elicit benefits to health and physical fitness. Other than one unpublished study into the intensity and EE of four of the 12 P90x® workouts, there is no apparent research into the P90x® home exercise program. Thus, the purpose of this study was to examine the effects of a 4 week bout of P90x® on upper (US) and lower body muscular strength (LS) and upper (UE) and lower body muscular endurance (LE), lower limb mean anaerobic power (MP), and body composition (%BF) changes. It was hypothesized that adaptations in US, LS, UE, LE, MP, and %BF would show significant improvements as a result of the 4 week training, with muscular endurance and body composition showing the most significant improvements.

CHAPTER II

LITERATURE REVIEW

With increasing technological advances diminishing the need for physically intensive jobs as well as decreasing physical activity in daily life, incidences of child and adult obesity have been increasing and the prevalence of exercise in adults is low. The low prevalence of exercise could be attributed to perceived barriers to exercise inhibiting individuals from participating in daily exercise activities. A lack of time for exercise is often regarded as the most frequent and strongest perceived barrier to exercise. Certain types of exercise, CRT and HIIT, have been shown effective at increasing components of fitness with a significantly lower volume of training and a significantly shorter time commitment than typical moderate-intensity, continuous exercise. Therefore, a home exercise program which uses components of HIIT and CRT could potentially mitigate many perceived barriers to exercise and increase the prevalence of exercise in adult populations. One such home exercise program exists which is a widely known and highly marketed DVD-based product: P90x®.

Prevalence of Physical Activity and Exercise

The need for physical activity and exercise in healthy adults, as well as other populations, has been established (Haskell et al., 2007). However, despite standard recommendations for physical activity described by Haskell et al. (2007), nearly half of adults 18 years of age and over in the United States meet neither the minimum recommendations for aerobic activity nor the minimum recommendations for muscle strengthening activity (National Center for Health Statistics, 2012). The National Center for Health Statistics (2012) reported that 47.3% of adults age 18 years and older in the United States do not meet the minimal recommendations for aerobic activity, 24.4% do not meet muscle-strengthening recommendations, and 49.1% meet neither. Additionally, 39.7% do not engage in any leisure-time physical activity (LTPA), 21.9% engage in light-moderate LTPA at least 5 times per week, and only 11.1% engage in vigorous LTPA 5 times per week.

Barriers to Physical Activity and Exercise

Several barriers or perceived barriers may play a role in the low documented levels of exercise and physical activity. Lack of access to facilities, time, financial cost, and lack of an exercise partner have been reported as common barriers to physical activity and exercise (Brinthaupt, Kang, & Anshel, 2010; Godin et al., 1994). Data in these types of studies are often reported as either frequency (how often a barrier interferes with exercise) or strength (likelihood of a barrier interfering with exercise).

Time. Godin et al. (1994) examined the relationship between perceived barriers to exercise and high or low intention to exercise; three different samples were used (general population; coronary heart disease individuals; and pregnant women) to determine the degree to which perceived barriers influenced the intent to exercise. The researchers noted that in the general population, time requirements for exercising was the most common barrier as well as the strongest barrier to exercise. However, even among the general population, there was a difference noted in the strength of barriers reported by individuals with a high intent to exercise and a low intent to exercise. Whereas high intenders reported lack of time as the strongest barrier, the strength of the barrier was weaker than that reported by low intenders. Overall, those with a high intent to exercise evaluated barriers to exercise to have a generally weaker effect on their intent to exercise than did low intenders. The authors noted that even with persons possessing a high intention to exercise, perceived barriers showed a negative relation to the intention to exercise. Despite the differences between high and low intenders, difficulty in finding time to exercise showed the greatest strength as a barrier to exercise when both groups were combined with lack of an exercise partner and physical health problems being the next strongest barriers, respectively. Lack of access to a sporting facility and financial costs of exercising were reported as the weakest barriers overall. Time required for exercise was also observed to be the only common perceived barrier among all three groups examined; the authors noted that lack of time has also been observed by several other authors on multiple occasions and concluded that time requirements are a universal barrier for any sedentary individual.

Brinthaupt et al. (2010) conducted a study examining the effects of a delivery model for overcoming psycho-behavioral exercise barriers. A psycho-behavioral barriers inventory in the form of a 5-point Likert scale (1 = *not at all*, 2 = *slightly*, 3 = *possible*, 4 = *likely*, 5 = *very likely*) was used to rate the degree of 11 psychological, behavioral, and environmental barriers applied to the participant as a reason that may inhibit the participant from starting or maintaining an exercise program. Participants were assigned a fitness coach for the duration of the 10-week intervention. A disconnected values inventory was used to determine five negative habits that affected participant health, happiness, energy, and quality of life. After determining benefits, short-term costs, and long-term consequences of each negative habit, participants were able to pick at least one of the habits that was unacceptable given the costs and consequences of that habit. An action plan was then developed to replace unhealthy habits with more desirable, healthy routines. The fitness coach assisted participant adherence to these action plans. Both pre- and post-intervention, “not enough time” was reported as the highest rated exercise barrier.

Reports of lack of time as a perceived barrier show similar frequency and strength in university samples. A survey of 1,044 college students conducted by Ebben and Brudzynski (2008) showed “no time” as the most common reason, reported by 69.6% of participants. However, “school work” was also a survey option; too much school work could likely be included in the “no time” category and, thus, affect the survey results by further increasing the frequency of “no time” being reported as a barrier to exercise. However, during a study conducted by Grubbs and Carter (2002), time as a barrier for exercise was reported as the fourth strongest perceived barrier to exercise based on a 4-point reverse Likert scale (1 = strongly agree to 4 = strongly disagree) in a survey of 147 college undergraduate students. Despite this differing report in the strength of lack of time as an exercise barrier, it was reported as the most mentioned personal barrier to exercise.

Lovel, Ansari, and Parker (2010) assessed benefits and barriers of exercise in 200 female students from two universities in south England with an Exercise Benefits and Barriers Survey (EBBS) questionnaire. Results from the questionnaire showed that while physical exertion was reported as the greatest perceived barrier to exercise, time expenditure followed in second although it was significantly less reported than physical exertion. While there was no significant difference between time expenditure and family discouragement or exercise milieu, time exertion was considered to be a greater barrier.

Another study of Turkish university students (Daskapan, Tuzun, & Eker, 2006) showed similar results as those of Lovel et al. (2010). A questionnaire consisting of 12 items rated on a 5-point Likert scale was sent to 303 students attending the university's undergraduate program in order to determine perceived barriers to exercise. Perceived barriers were divided into two categories: internal and external barriers. Internal and external barriers were grouped into 3 categories each: lack of energy, lack of motivation, and lack of self-efficacy (internal) and lack of resource, lack of social support, and lack of time (external). Lack of time was reported as the most important external perceived barrier for both males and females.

Reports of lack of time as a perceived barrier in other populations show similar trends. Bautista, Reininger, Gay, Barroso, and McCormick (2011) conducted a survey of a sample of 398 Hispanic adults. Lack of time for exercising was reported by at least 40% of all participants. Bautista et al. (2011) reported that these results are similar to those found in multiple studies of Mexican-American adults with type-2 diabetes (T2D), immigrant Latinas, and older women. The authors also stated that "lack of time" has been found to be a significant correlate of physical activity in other samples of adult men and women as well. Andajani-Sutjahjo, Ball, Warren, Inglis, and Crawford (2004) conducted a survey of 445 Australian women who provided data out of an initial 1,200, aged 18-32 years, selected through stratified random sampling of the Australian Electoral Roll. Time concerns as a perceived barrier were included in factor 3 (environmental barriers to physical activity) of 5 factors. Results from this study showed that motivation, time, and cost were the main barriers reported by young women. In regards to time as a perceived barrier, work commitments (58%) were reported more often as a barrier than lack of time due to family commitments (37%) (Andajani-Sutjaho et al., 2004). Another survey of Australians (aged 20 to 65 years) reported lack of motivation and time to be the most frequently reported barriers to exercise and the only barrier to independently contribute to variations in the amount of weekly leisure time physical activity (Cerin, Leslie, Sugiyama, & Owen, 2010). Additionally, lack of motivation and time were reported as higher in younger, female, and overweight or obese respondents (Cerin et al., 2010).

Lack of time as a perceived barrier to exercise is highly reported among multiple populations and studies. Additionally, while also frequently the most common perceived barrier reported, lack of time has also been shown to frequently be the strongest barrier reported. These trends are true across age ranges, race, nationality, and regardless of whether an individual has a high or low intent to exercise. Therefore, Godin et al.'s (1994) conclusion that time requirements are a universal barrier for all sedentary individuals appears accurate and supported by the research literature.

Lack of access to facilities. Lack of access to exercise facilities is often found as an option in many perceived barriers surveys. However, while lack of time is reported frequently and as a strong perceived barrier, lack of access to facilities is generally reported much less frequently and as a weaker external barrier.

Godin et al. (1994) found "lack of access to sporting facilities" to be the weakest of the five barriers measured in their study. Brinthaupt et al. (2010) also found "no close access to exercise facility" to be one of the three least likely exercise barriers in their study. Ebben and Brudzynski (2008) observed that only 10 (4.2%) of the 240 participants surveyed reported “inconvenient location” as a barrier to exercise for non-exercisers and 14 (4.0%) of 214 participants reported that a “better facility location” would lead them, as non-exercisers, to begin exercising. Cerin et al. (2010) reported “lack of facilities” as positively and independently related to the odds of nonparticipation in LTPA and that it is possible that this barrier plays a significant role in whether or not a person engages in LTPA, but not in determining the amount of activity in those who participate in LTPA. Daskapan et al. (2006) also reported a relatively weak measure of lack of access to facilities as a perceived barrier using a 5-point Likert scale and reporting results as mean ± standard deviation (*M* ± *SD*) with “there is no fitness center I could get to” (2.52 ± 1.23) ranking with eight measures greater than its value and only three weaker for males and females combined, with no significant difference between sexes.

Lovel et al. (2010) examined perceived barriers by way of category sub-scales with a 4-point Likert scale (1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree) and reported results as *M* ± S*D*. While “places for me to exercise are too far away” and “there are too few places for me to exercise” were reported under the exercise milieu sub-scale, which was the third strongest of 4 categories, “places for me to exercise are too far away” was reported as the strongest (2.69 ± .70) of all individual perceived barrier items. Bautista et al. (2011) found that, in Hispanic adults, “lack of a safe and convenient place to do exercise” was reported to have a prevalence of 16.4% in males and 26.7% in females while the prevalence among exercise groups was reported as 37.9% (*n* = 116) for non-exercisers (NE, no engagement in exercise for past 30 days), 15.4% (*n* = 136) for exercisers not meeting physical activity guidelines (ENM), and 21.5% (*n* = 121) for exercisers meeting physical activity guidelines (EM). These results are indicative of lack of access to facilities being a stronger barrier in non-exercisers than in either ENM or EM and a stronger barrier for women than for men. Andajani-Sutjahjo et al. (2004) similarly report that of 445 young women (age 18-32 years) who completed their survey, 34% found “not having access to places to do physical activity, exercise or sport” to be a barrier (29% a somewhat important barrier, 11% a very important barrier) while the majority (66%) reported that it was not a barrier.

Results from these studies provide evidence that lack of access to facilities as a perceived external barrier to exercise and physical activity can vary greatly between populations. However, generally a lack of access to facilities is infrequently reported and weak as a perceived barrier to exercise.

Lack of an exercise partner. As a perceived barrier to exercise, lack of an exercise partner is less frequently investigated than other categories. However, results from some studies that have examined it have shown that it can be a significant barrier to exercise and physical activity.

Brinthaupt et al. (2010) discovered that, among 11 barriers examined in 58 participants, “no exercise partner” was reported as the median in strength among the barriers examined both pre- and post-test. Ebben and Brudzynski (2008) found that, in 240 non-exercising college students (20.53 ± 5.77 years of age) surveyed about barriers to exercise, only 5% (n = 12) reported “no exercise partner” as a barrier to exercise. However, of 214 participants who completed the portion of the survey “what would lead non-exercisers to begin to exercise,” 10.2% (n = 36) reported a workout partner or group would lead them to begin exercise. Of the higher order themes reported for factors that would lead non-exercisers to begin to exercise, only “more time” was reported more frequently (25.9%) than “workout partner or group” (10.2%) as a perceived barrier to exercise.

Similarly, Godin et al. (1994) utilized a 7-point scale from -3 (unlikely) to +3 (likely) to survey participants about the probability that a barrier to exercise would impede them from regularly exercising. Values reported in parenthesis are mean scores for a given category based on the 7-point scale used. Godin et al. observed that “difficulty in getting an exercise partner” (-.74) was reported in the total general population (n = 349) as the second strongest perceived barrier, with “difficulty in finding time to exercise” (-.10) being the only barrier that was stronger. Additionally, within participants with a low or moderate intent to exercise (n = 145) “difficulty in finding an exercise partner” (-.39) was reported as the strongest perceived barrier while in participants with a high intent to exercise (n = 204), it was reported as only the third strongest perceived barrier (-.99), being lower than “difficulty finding time to exercise” (-.47) and “physical health problems” (-.91), respectively.

Bautista et al. (2011) reported that in Hispanic men surveyed (n = 61), 19.7% reported “nobody to do exercise with” as a barrier and 21.9% of women (n = 333) reported it as a barrier. Separated by exercise groups, “nobody to do exercise with” was reported as a barrier by 23.3% (n = 116) of non-exercisers, 21.3% (n = 136) of exercisers not meeting physical activity guidelines, and 19.0% (n = 121) of exercisers meeting physical activity guidelines. There was no significant difference in the reported values of the prevalence of “nobody to do exercise with” as a barrier among exercise groups. However, overall “nobody to do exercise with” as a perceived barrier in the study by Bautista et al. (2011) is similar, with lack of an exercise partner as a perceived barrier being approximately the middle barrier in frequency reported in Brinthaupt et al. (2010) where lack of an exercise partner was the middle barrier in strength reported.

Results from these studies provide evidence that lack of an exercise partner can vary in strength as a perceived barrier to exercise or physical activity depending on the population sampled. However, across the studies reviewed, lack of an exercise partner was often reported as at least a moderate-to-high perceived barrier to exercise or physical activity.

Financial cost. With economic concerns within the economy of the U.S., financial cost of exercise facilities or safe places to perform physical activity, could be a barrier for many individuals. Several researchers examined some aspect of financial cost as a perceived barrier to exercise using Likert scales and frequency data.

Ebben and Brudzynski (2008) examined exercise motivations and barriers in college students and found that “cost” was reported by 3.3% ($n = 8$) of 240 participants as a barrier to exercise for non-exercisers. As a factor that would lead non-exercisers to begin exercise, “lower cost” was only reported by 1.4% ($n = 5$) of 214 participants as a reason that would lead them to begin exercising. For both categories, the reported values for cost were low on the frequency scale compared to other higher order themes. Similarly, Brinthaupt et al. (2010) found, of 11 exercise barriers reported, “too expensive” (1.59 ± 1.06) was the next to weakest barrier, with only “fear of injury” (1.55 ± .68) being weaker for pre-test measures. Within post-test measures, “too expensive” (1.33 ± .82) and “fear of injury” (1.33 ± .66) were nearly identical and the weakest barriers reported. In contrast, Andajani-Sutjahjo et al. (2004) found reported values of financial cost as “not being able to find physical activity facilities that are inexpensive” to be reported by 51% of participants (n = 445) as a barrier to physical activity (29% somewhat a barrier, 22% a very important barrier) and 49% of participants reporting it as not a barrier.

In their study of exercise intention and perceived barriers, Godin et al. (1994) found "financial cost of exercising" to rank fourth (-1.07 ± 1.65) of five barriers in terms of strength for the total general population of all intenders (n = 349). The strength of the values for both the low or moderate intenders (n = 145) and high intenders (n = 204) remained consistent to the total as the second weakest barriers at -.86 ± 1.67 and -1.23 ± 1.61, respectively. It is, however, of interest to note that there was a significant difference ($p < .05$) in the strength of the values reported by low or moderate intenders and high intenders, with high intenders reporting "financial cost of exercising" as a significantly weaker barrier to exercise.

In the study conducted by Lovell et al. (2010), financial cost was reported through the perceived barrier item "it costs too much money to exercise" as an index of the strength of the barrier as a mean and standard deviation. Financial cost was reported as the second strongest (2.26 ± .86) of 6 perceived barrier items on the exercise milieu sub-scale. The only item reported as stronger in this sub-scale was the item "places for me to exercise are too far away" (2.69 ± .70).

Financial cost is often reported as a perceived barrier to exercise and physical activity. As with "lack of an exercise partner" the strength and frequency of financial cost as a perceived barrier to exercise can vary by population. However, the frequency and strength of the barriers are generally reported less frequently than other barriers and as a weaker barrier to exercise overall.

Perceived barriers to exercise and physical activity can be strong and frequently reported causes for individuals to refrain from participation in exercise and physical activity. However, it has been shown that the strength and frequency of these barriers can be lowered through intervention. The most common and frequently reported perceived barrier to exercise is lack of time. Lack of an exercise partner is less frequently reported than time as a perceived barrier, but has been shown to be a moderate-to-high perceived barrier to exercise across samples. Lack of access to facilities has generally been reported infrequently and as an overall weak barrier, although reported frequency and strength is shown to vary based on sample demographics; therefore, results could be heavily influenced by sample and location. Financial cost as a perceived barrier to exercise has been reported to have similar frequency and strength as lack of an exercise partner with results varying based on the sample. An exercise program that specifically neutralizes or decreases the relevance of these barriers could be key to increasing exercise and physical activity in a population. Circuit resistance training and HIIT can potentially address perceived exercise barriers such as time, while utilizing these forms of training through a home-based program could further reduce perceived exercise barriers.

Physiological Adaptations to Circuit Resistance Training

Circuit resistance training is typically defined as a series of resistance exercises performed in a sequential order with minimal rest, typically 15-60s, between exercises with one or more complete circuits being performed. This type of exercise has been observed to induce significant improvements to a number of components of physical fitness. Improvements to aerobic power (VO_{2max}), muscular strength and endurance, and body composition are important for sedentary or overweight to obese populations for the prevention of disease or reduction of disease signs or symptoms. Circuit resistance training has also been observed to elicit improvements to physical fitness in significantly less training time than typical resistance or endurance training programs. As a result, CRT could be effective at reducing or eliminating several perceived barriers to exercise, primarily lack of time.

Cardiovascular response, VO_2, and energy cost. Circuit resistance training of a high volume has been found to provide a cardiovascular component significant enough to elicit a cardiovascular training response, although the aerobic training response is less than a typical aerobic training protocol (Gotshalk et al., 2004). Gotshalk et al. (2004) conducted a study with 11 college males (20.1 ± 1.9 years) who had just completed an 11 week resistance training program and were considered to be fit. The training protocol conducted was designed to be of a demanding nature in an effort to elicit the recommended intensity levels necessary to affect variables of cardiovascular fitness. The CRT test protocol consisted of 10 lifts for 10 repetitions each at 40% of 1 repetition maximum (RM) values with little to no rest between exercises other than 2 to 5 seconds required to move to the next station. Approximately 4.6 circuits were completed by each participant. The high-volume continuous CRT training program did not resemble a typical cardiovascular endurance training programs utilizing a treadmill where heart-rate (HR) and VO_2 increase proportionally. The HR/VO_2 ratio for this CRT program was not linear; HR continued to increase after VO_2 stabilized after approximately 7 minutes of exercise. At the same heart rate levels, VO_2 in this CRT protocol was significantly lower than treadmill running. Despite the cardiovascular response being significantly lower than a typical treadmill endurance regimen, CRT did elicit a cardiovascular response substantial enough to induce training adaptations. Additionally, while the VO_2 response is lower, CRT provides training with a high metabolic demand and cardiorespiratory demand for multiple muscle groups, while typical running endurance protocols primarily utilize lower limb muscle groups.

In contrast to the high-volume CRT protocol utilized by Gotshalk et al. (2004), Alcaraz, Sanchez-Lorente, and Blazevich (2008) examined cardiovascular responses in an acute bout of heavy resistance circuit (HRC) compared to a traditional strength (TS) training protocol. Participants in both HRC and TS groups trained at individual 6RM resistances. The HRC training consisted of a circuit of five sets of bench press to volitional fatigue followed by one set each of leg extensions and ankle extensions, with 35 seconds of rest between each exercise included in a total of 3 minutes of active rest between each bench press set. The TS training was composed of five sets of bench press to volitional fatigue with each set separated by 3 minutes of passive rest. The HRC provided a significantly greater cardiovascular response than did TS, while not affecting participant ability to perform the concentric phase of bench press, demonstrated by no significant differences in bar velocity between the 2 groups, and maintaining the same volume of repetitions between the 2 groups. Heart rate values achieved by HRC were up to 71% of maximum values, while TS were up to 62% of maximum values, putting HRC within the recommended range of intensity recommended (60 - 90%) by the American College of Sports Medicine (2014) needed to develop cardiorespiratory fitness and to promote body composition changes; TS, in contrast, was at the low end of this range. These data indicate that HRC allows for a similar volume of strength training for a muscle group as TS while eliciting a significantly higher level of intensity by including multiple muscle groups allowing for active rest of a muscle group between sets. In this way, more work is performed in a shorter period of time.

Results similar to those found by Alcaraz et al. (2008) and Gotshalk et al. (2004) were observed previously by Wilmore et al. (1978). Wilmore et al. (1978) measured test variables twice on separate days during a circuit training session involving 10 stations of exercises with 30 seconds of exercise per station and 15 seconds of exercise between stations and a recovery period of 12 minutes following the completion of three complete circuits. Resistance used was equivalent to 40% of participant 1RM values. The results of this study showed a non-linear relationship between HR and VO_2 when men worked above 70% of their HR_{max} and below 45% of maximal aerobic capacity (VO_{2max}) while women worked above 80% and below 50%, respectively. These values of % HR_{max} are similar to those observed by Alcaraz et al. and values of HR_{max} in relation to increase in VO_2 is similar to what was found by Gotshalk et al. Wilmore et al. also observed that EE of this type of circuit resistance training protocol was about 9 kcals/min for men and 6.1 kcals/min for women which is sufficient for weight control and weight loss with no change in diet. The researchers did note, similar to Gotshalk et al., that the reason for the non-linear increase in HR_{max} and VO_{2max} is likely due to the increased use of upper-body muscles as compared to the linear increase in these values using the larger muscles of the lower body while leg cycling or running.

In a study of high-velocity circuit training, Peterson et al. (1989) measured maximal stroke volume and VO_{2max} pre- and post-test for both training and control groups. The training group completed 21 circuit training sessions over 42 days; training sessions consisted of two circuits of 10 variable resistance exercises for the first 2 weeks and three circuits during each exercise session after the first two weeks. During all training sessions, there was an exercise to relief ratio of 1:2 with two 20 second sets of maximal effort at each exercise station separated by 20 seconds of rest with 1 minute of rest between each station and 4 minutes rest between each circuit. Control participants were allowed up to three low-intensity aerobic sessions per week and one heavy resistance training session per week in order to maintain pre-test fitness levels (Peterson et al., 1989). There was a significant increase in VO_{2max} in both relative and absolute terms from pre- to post-test measures while the control participants showed a decrease, though not significant. Heart rate max values showed no significant difference between pre- and post-test measures for either group. There was a significant increase in maximal stroke volume in the training group, but a non-significant decrease in the control group. The results indicated that high-velocity circuit resistance training can increase maximal stroke volume and cardiac output by approximately 8% in previously trained participants without a significant increase in HR and that this type of training may also be an effective mode of training to stimulate aerobic fitness as evidenced by an 8% increase in VO_{2max} in both relative and absolute terms.

Circuit resistance training has also been shown to be effective in sedentary populations. Kaikkonen, Yrjämäm, Siljander, Byman, and Laukkanen (2000) examined the effects of HR controlled low resistance circuit resistance training compared with typical endurance training in sedentary adults over a 12 week training period. Specifically, the researchers were interested in the effects of these training modes on aerobic power in this population. This study was also the first to examine CRT with loads of 20% of 1RM values. Training groups consisted of a circuit weight training group

(CWT) which performed 12 weeks of 40 minute training sessions three times per week on an HUR air resistance machine, with each training session being comprised of 3 full circuits of 10 exercise stations with a work-to-rest ratio of 2:1 (40 seconds/20 seconds); an endurance group (END) which could choose to walk, bicycle, cross-country ski, or jog for 40 minutes, 3 days per week at the same HR level as the CWT group; and a control group which did not change exercise or other living habits. Results from this study indicate that, in a sedentary adult population, HR controlled low resistance circuit weight training can significantly improve VO_{2max} as well as significant increases in muscular strength and endurance over 12 weeks. Improvements in aerobic power were not statistically different than those in the END group. These data also provide evidence that HR controlled exercise is a reliable method to progressively increase intensity as participants improve over time, at least in a sedentary population, because as the work becomes easier, average HR declines and work must be increased to stay within the target HR range. Overall, this study demonstrated that circuit resistance training protocols can be modified to accommodate sedentary populations and elicit significant muscular and cardiovascular improvements.

Rather than an extended training period, Mukaimoto and Ohno (2011) examined differences between low-intensity circuit resistance exercise with slow movement, low-intensity circuit resistance exercise with normal movement, and high-intensity resistance exercise with normal movement over single exercise sessions. Intensity was based on participant 1RM and the key variable measured was oxygen consumption both during and after training sessions. Low-intensity circuit resistance training with slow movement showed significantly greater total EE and total VO_2 while eliciting lower blood-pressure values than both low-intensity normal movement and high-intensity normal movement. However, these differences in total EE and oxygen consumption are likely due to duration, as the duration of the low-intensity slow movement group was significantly longer than both the low-intensity normal and high-intensity normal groups. Regardless, these results indicate that even a low-intensity circuit resistance program with slow exercise movement speed can significantly increase total EE and total VO_2 while eliciting a significantly smaller increase in blood pressure than higher intensity circuit training types which could be particularly beneficial to more sedentary or high-risk adults. These results could also be more significant in sedentary populations, due to these significant results being observed in a healthy, previously trained population of adult men. The researchers also proposed that there may be an optimal work-to-rest ratio to maximize total oxygen consumption and total EE, as their review of literature provided evidence that intensity or volume of exercise alone cannot account for increases in duration or magnitude of excess post-exercise oxygen consumption (EPOC).

Another study on EPOC with circuit resistance training was conducted by Haltom et al. (1999). In their study, Haltom et al. had both a 20-second rest interval group (20RI) and a 60-second rest interval group (60RI) exercise at 75% of participant’s 20RM value and ensured identical exercise intensity by controlling exercise repetitions with a metronome. The researchers found that the total EE between the two groups was significantly different, but both had positive benefits depending on participant preferences. The 20RI group achieved slightly fewer calories expended than the 60RI group per session, but if a participant is tolerant of the higher intensities, this slightly lower EE is achieved in half the time as 60RI. Conversely, if participants are not as tolerant of high-intensity exercise or can fit the extended duration of exercise into their schedule, a 60-second rest interval would elicit slightly higher caloric expenditure per session.

A study examining changes associated with circuit weight training alone and circuit weight training combined with running was conducted by Gettman, Ward, and Hagan (1982). In this study, the circuit weight training (CWT) group performed a circuit of 30 seconds per exercise station with 15 seconds of rest between stations. At each of the 10 stations, the participants worked at 40% of 1RM values for 12-15 repetitions. Participants in the running and circuit weight training combined (RUN-CWT) group performed the same circuit, but with 30 seconds of running following each 30 second exercise station at a running speed which would elicit 60% of maximal HR. Results indicated that both training groups were effective at increasing VO_{2max}, with results being slightly higher in the RUN-CWT group, though not significantly so. However, both groups showed significant improvement in aerobic power (17%) compared to a control group. Additionally, these improvements were accomplished in 22.5 minute and 30 minute training sessions 3 days per week for 12 weeks. These results are indicative that both a CWT and RUN-CWT protocol elicit similar results and are within typical aerobic power improvement ranges of other aerobic training programs and could be used either as a substitute for running programs for individuals experiencing orthopedic stress or as a pre-running program training protocol. Even as stand-alone training protocols, both methods of circuit training produce significant improvements in aerobic power.

Messier and Dill (1985) found that VO_{2max} improved by 10.8% in a circuit resistance training protocol conducted on Nautilus fitness equipment. The researchers compared three different training groups exercising 3 days per week for 10 weeks. The Nautilus circuit group utilized 8-12 repetitions for upper body and 15-20 repetitions for lower body for 12 prescribed exercises; the running group participated in progressive running training for an average of 30 minutes per day at 60-90% of HR reserve (HRR); and the resistance training protocol, which also served as the control for aerobic power, utilized free-weights for 3 sets of 6 repetitions and approximately 75% 1RM value with a work to rest ratio of 15:30 seconds. Messier and Dill found that over 10 weeks of training, aerobic power improvements for the run group (11.7%) and for the Nautilus circuit group (10.8%) were similar, but both were significantly greater than the resistance group. These results are comparable to those found by Gettman, Ward, and Hagan (1982) where a circuit group averaged approximately a 12.5% increase in aerobic power for males and females combined after 12 weeks of training. These results provide evidence that, for improvement of aerobic power, circuit resistance training is similar to traditional running endurance training in non-trained individuals. As with Gettman et al., these data support circuit resistance training as a viable alternative to running at increasing aerobic power in sedentary individuals.

In contrast, previous research by Gettman, Ayres, Pollock, and Jackson (1978) showed different results. In this study, the researchers also examined a CRT group, traditional resistance group, and a control group. Where results differ from the previous studies is that Gettman et al. (1978) observed that while lean body weight was not accounted for, improvements in aerobic power were similar between the run group and circuit group and both were significantly higher than the control group. However, when lean body weight was accounted for, the run group showed improvements to aerobic power greater than could be explained by increases in lean body weight could account for alone, indicating that the run training was better at increasing aerobic power. Inversely, increases in aerobic power in the circuit group were primarily due to increases in lean body weight, not due to increases in oxygen delivery potential.

Overall, the available literature supports the use of CRT to improve aerobic power. While some literature reviewed does present different results, indicating that CRT may not be as effective as traditional running endurance programs at increasing aerobic power, CRT can still provide significant improvements while meeting minimal recommendations for aerobic activity for the improvement of health and fitness (American College of Sports Medicine, 2014). In addition, despite the potential differences in improvement to aerobic power, CRT also shows significant improvements in other key areas, primarily muscular strength and endurance and body composition, that running endurance programs alone cannot provide.

Muscular adaptations. Circuit resistance training programs focusing on heavy resistance have also been shown to provide similar benefits in muscular strength adaptations compared to typical strength training programs, while maintaining a moderate-high cardiovascular component (Alcarez et al., 2011). The American College of Sports Medicine (2014) recommends muscle strength and endurance training for each major muscle group 2-3 days per week for healthy, adult populations. Circuit resistance training can easily meet these recommendations for training muscular strength and endurance while eliciting a moderate to vigorous aerobic intensity relative to $\%HR_{max}$.

A 10-week study of circuit resistance training in untrained men and women conducted by Wilmore et al. (1978) found that CRT significantly increased strength in both men and women, though improvements for men were of a smaller magnitude than was expected. The researchers attributed this small magnitude as being potentially due to insufficient training intensity. Gettman et al. (1982) observed similar results when examining a RUN-CWT group and a CWT group. As with Wilmore et al., Gettman et al. observed that women demonstrated 22% and 19% increases in strength in RUN-CWT and CWT groups respectively, while men demonstrated 21% and 15% increases in strength. Despite the smaller magnitude of improvement in the males, both males and females showed significant increases in strength for both training groups when compared to the control groups.

In an earlier study, Gettman et al. (1978) examined a CWT group compared with run only (RN) and sedentary control groups (CON) in male police officers. Over the course of a 20-week training period, the CWT group showed significantly greater improvement ($p < .01$) in bench press strength than both the RN and CON groups. Overall increases in bench press strength were 32.6% for CWT (from 153 to 203lbs) compared to only 12.5% (from 151 to 170lbs) in the RN group and no significant change in the CON group. Similarly, Harber, Fry, Rubin, Smith, and Weiss (2004) observed a 37% increase in 1RM chest press strength over a 10-week CRT program utilizing resistance between 40% - 60% 1RM. These increases in strength are similar in the studies by Harber et al. (2004) and Gettman et al. (1978), but both are noticeably different than those found in males by Gettman et al. (1982). Differences in strength improvements could be attributed to the length of the training programs which were 20-weeks (Gettman et al., 1978), 10-weeks (Harber et al., 2003), and 12-weeks (Gettman et al., 1982) as well as differences in resistance. Considering that Harber et al. (2004) observed results in strength improvement similar to those found by Gettman et al. (1978), with a training period half as long, while also showing noticeably larger strength improvements than those found by Gettman et al. (1982) in less time, it is likely that these strength adaptations are primarily due to resistance used rather than the duration of the training programs.

Whereas Gettman et al. (1978) examined circuit weight training and running groups independently of one another, Chtara et al. (2008) similarly examined high-intensity endurance run training (E) and strength circuit training (S), but also included groups for endurance training before strength circuit (E+S) and strength circuit before endurance training (S+E) in order to examine sequence effects over 12 weeks of training. The first six weeks of circuit weight training focused primarily on strength endurance while the final 6 weeks focused on explosive strength and power. The high intensity endurance run training consisted of high intensity interval sprints at participant VO_{2max} over five intervals with a period of active recovery following each interval at 60% of VO_{2max}. Training was the same for E+S and S+E groups, with the only difference being the sequence of training. Following the 12 week training period, all training groups increased strength significantly ($p < .01$) while C showed no significant difference. However, the S group demonstrated a significantly greater increase in strength than both the E+S, S+E groups, and E groups, despite both E+S and S+E having significantly greater improvements than E. These results are potentially indicative of high intensity interval running having a detrimental effect on strength development, even when combined with a circuit strength training program. Regardless, all modes of training that included CRT demonstrated significantly greater increases in strength than endurance only or a sedentary control.

Where the majority of past research has examined the effects of CRT with low-to-moderate resistance intensities, another study instead compared traditional strength training (TS) and heavy resistance circuit training (HRC; Alcaraz et al., 2011). The only difference in training between the HRC and TS groups in this study was in the rest periods between exercises. Both groups utilized a weight equivalent to participant 6RM (85 - 90% 1RM) which is far greater than resistances commonly used in previous research. Alcaraz et al. (2011) found no significant difference in strength improvements between HRC and TS, though both groups showed significantly greater strength improvements than the control (CON) group. Pre- and post-test values for strength are not shown within the data so it is difficult to accurately compare results from this study to those of others. Regardless, these results demonstrate that a HRC training protocol can elicit results similar to that of a TS program in less time. This difference could be of particular appeal to those who perceive time as a barrier to exercise and physical activity.

Muscular strength and endurance alterations consequent to CRT have been demonstrated to vary depending on resistance used, rest intervals used, and duration of training protocol. Across all reviewed literature, strength and endurance changes have increased significantly when compared with control groups, whether in trained or untrained participants. Additionally, when heavy resistance loads are used, strength adaptations in CRT are similar to those found in traditional strength training programs. These similar improvements in muscular strength are achieved in less time per training session than traditional strength training programs. Reduced time required for training could alter the frequency and strength of time as a perceived barrier to exercise and physical activity when introduced to participants who perceive time as a strong or frequent barrier.

Body composition. Body composition, primarily %BF, is a primary focus for improvement in many individuals. Excess body fat has been well established as a cause for increased risk for disease. Therefore, in addition to improvements in functional fitness such as muscular strength and endurance and aerobic power, improvements in body composition are critical for the maintenance of health and fitness. Circuit resistance training has been demonstrated to provide improvements to muscular strength and endurance and aerobic power while simultaneously improving body composition.

Wilmore et al. (1978) recruited male (n = 26) and female (n = 23) participants to participate in 10-weeks of an intervention assigned to either a control group or experimental group. The experimental group participated in 10-weeks of CRT at a rate of three circuits per day for 3 days per week. Exercises in the circuit utilized resistances equivalent to 40 - 55% of participant 1RM; each exercise was performed for 30 seconds with as many repetitions performed as possible. Rest intervals of 15 seconds were allotted between exercise stations to account for movement between stations. Resistances were increased as necessary throughout the 10-week intervention to account for participant strength improvements. There were no significant changes in total body mass or fat mass in men or women, or in relative fat mass for men. However, significant increases were observed in lean body mass for both men and women, with a significant decrease in relative fat mass in women.

Messier and Dill (1985) included anthropometric changes as a variable in their study, although it was not the primary purpose of the research. Anthropometric differences were observed between 3 training groups: free weight training (FW), Nautilus circuit weight training (N), or running (R). The training for the FW group closely resembled training typically considered as traditional strength training, where a resistance of 75% 1RM was used for all lifts for three sets of six repetitions with a 1:2 work/rest ratio between sets. Exercises approximating those used by the FW group were used by the N group on Nautilus resistance equipment. Resistance used for the N group was selected to elicit a minimum of 8 repetitions, but no more than 12 repetitions for upper body exercises and 15 - 20 repetitions for lower body exercises. Neither the number of circuits performed nor the work/rest ratio for the N group were provided. Training for all groups was conducted 3 days per week for 10 weeks. Following the 10-week intervention, body mass decreased in both N (Δ -.08 kg) and FW (Δ -.10 kg) groups and increased in the R (Δ +.21 kg) group. However, decreases in skinfold thickness (sum of 3 skinfolds; chest, abdomen, and thigh) were observed in all 3 training groups (N, Δ-10.47mm; FW, Δ -7.78mm; R, Δ -7.86mm); although, the N group showed a greater decrease in skinfold thickness than the FW group and the R group. While changes to anthropometric measures were observed, it is difficult to interpret the meaning of these values as Messier and Dill did not indicate whether any measures of anthropometry were statistically significant or non-significant. However, given the relatively small degree of change in body mass and the larger degree of change observed in skinfold thickness, it is likely that increases in lean body mass accompanied the decreases in skinfold thickness.

Chtara et al. (2008) observed changes in body mass (kg) and % body fat (%BF) pre- and post-intervention for 5 experimental groups. One group (E) participated in only high-intensity endurance run training, while another group (S) participated in only strength circuit training. Also, 2 groups were included to examine the effect of training sequence on variables: endurance before strength (E+S) and strength before endurance (S+E) with an additional group serving as a non-training control (C). Training was conducted for 12 weeks, although the frequency of training per week was not noted for any group. Results following the 12 week intervention indicated significant ($p < .01$) increases in body mass for the S, S+E, and E+S groups with no significant changes for either the E or C groups. Although non-significant, a decrease in body mass was observed in the E group. However, significant decreases in %BF were observed in all training groups, but not in the control group. These results demonstrate that CRT, even when combined with concurrent endurance training, is effective at increasing lean body mass while decreasing %BF, whereas the high-intensity endurance training group demonstrated decreases in body mass along with decreases in fat mass. Based on these observations, CRT or CRT combined with endurance training could be more effective at improving body composition than endurance training alone.

Harber et al. (2004) examined the effects of circuit weight training on 12 sedentary men aged 18 to 35 years. An exercise group (CWT) and a control group (CON) were utilized in this study. Training for the CWT group consisted of three training sessions per week for 10 weeks with 10 exercise stations per session at 40-60% of participant 1RM. The number of sets per training session as well as the work/rest ratio changed from week to week throughout the duration of the experiment. No significant changes ($p > .05$) were observed for any anthropometric variable (body mass, kg; lean body mass, kg; fat mass, kg; %BF) in either the CWT or CON groups, although effect sizes for the CWT group were moderate to small. It is unclear why no significant alterations to anthropometric measures were observed with this study. It is possible that these results are consequent to overall duration of the training intervention or the intensity of the training.

Brentano et al. (2008) calculated anthropometric measures before and after a 24 week intervention. Participants were postmenopausal women ($n = 28$) who all had bone loss and were participating in hormone therapy. Experimental groups for this study were strength training (ST, $n = 10$), circuit training (CT, $n = 9$), and a control group (CON, $n = 9$). Similar to results reported by Harber et al. (2004), results indicated no within- or between-group significant differences ($p > .05$) in body composition from pre- to post-intervention measures. However, despite these results not being significant, changes were observed in body composition. Fat free mass increased for both the ST and CT groups, with no change in the CON group. Fat mass decreased for the ST and CT groups, but increased in the C group. Skinfold measurements (mm) decreased in both training groups, but increased in the C group. Although these changes were not reported as significant, both training groups demonstrated improvements in body composition after 24 weeks of training.

In contrast, Gettman et al. (1982) did note significant changes in body composition over the course of a 12 week exercise intervention. Participants were males and females, age 36.1 ± 6.7 years and 35.7 ± 4.9 years respectively, placed into a CWT group, a RUN-CWT group, or a CON group. The only difference between the CWT and

RUN-CWT groups in terms of training was that rather than a 15-second rest period following each exercise station as performed in the CWT group, the RUN-CWT group ran for 30-seconds at a speed equivalent to 60% HR_{max} between each exercise station. Resistance used for both groups was equivalent to 40% of participant 1RM and all participants trained three times per week during the 12 week intervention. Results from this intervention demonstrated no significant differences in changes to body composition between the 2 training groups and no significant differences were observed in total body weight between any of the groups. However, when compared with the CON group, BF% decreases in the training groups were significant. Increases in lean body weight were significant for males in both training groups compared to male control groups while increases in lean body weight were only significant for females in the CWT compared to the female control group. It is of interest to note that significant improvements to body composition were observed in this 12 week intervention while none were observed by Brentano et al. (2008) in a 24 week intervention, even with similar exercise intensities and similar frequency of training per week. It is possible that the differences in results are due to differences in mean age of participants.

In a comparison of heavy resistance circuit training (HRC) to traditional strength training (TS), Alcaraz et al. (2011) observed significant changes in body composition between pre- and post-test measures. Alcaraz et al. (2011) recruited 40 previously trained men (age 22.7 ± 3.3 years) with 33 participants completing the study. Both the TS and HRC groups utilized the same exercises and resistances (6RM, 85-90% 1RM) with the only difference in training occurring in the rest intervals between exercises. The TS group used 3 minutes of passive rest between sets while the HRC group used 35 seconds between each exercise to facilitate movement between exercise stations. Changes in body composition between pre- and post-training measures observed for the HRC group were significant ($p < .05$) for both %BF (Δ-1.5 ± 1.6) and lean mass (Δ1.5 ± 1.9kg). The TS group only demonstrated significant changes in lean mass (Δ1.2 ± 1.6kg). No group showed any significant changes in total fat mass, demonstrating that changes in %BF were consequent to increases in lean body mass and not decreases in total fat mass. It is of interest to note that the greater improvements to body composition observed in the HRC group were achieved in approximately half the training time as the TS group. This difference in training time coupled with significant improvements to body composition could be vital in addressing time as a perceived barrier to exercise.

Ferreira et al. (2009) examined the effect of circuit resistance training on sedentary women. Healthy, sedentary women (N = 14; age 33 – 45 years) with a normal body mass index (BMI; 18.5 – 24.9 kg·m^{-2}) participated in this study. Body composition testing was conducted pre- and post-training via dual-energy X-ray absorptiometry (DEXA). The CRT protocol implemented for the intervention consisted of 10 weeks of training, at a frequency of three sessions per week utilizing nine exercise stations. Each training session consisted of two rounds through the circuit of nine exercises with 1 set of 8 – 12 RM at each station. Resistance loads were adjusted as necessary throughout the intervention to maintain the RM range. Rest intervals were 1 minute between each exercise station until the end of the 2 rounds of the circuit. Changes in body composition were evident between pre- and post-training measures. Total body mass did not significantly change; however, total body fat mass decreased significantly (kg; p =.02), lean body mass (kg) increased significantly (p = .0006), and BF% decreased significantly

(p = .01). These alterations to body composition were achieved with longer rest periods between exercise stations (60s) than are typically utilized (15 – 35s) in CRT with this range of RM (Alcaraz et al., 2011; Gettman et al., 1982; Wilmore et al., 1978). Results from this study provide evidence that CRT can elicit positive alterations to body composition in sedentary populations while allowing for a lower intensity by utilizing rest periods >35s.

Utilization of CRT has frequently been observed to provide significant positive alterations to body composition across a range of samples. These alterations are evident in CRT alone; CRT combined with run training; with heavy resistances (85 – 90% 1RM) and lighter resistances (40 - 60% 1RM); and with varying periods of rest between exercise stations within a circuit. Additionally, positive alterations to body composition have been observed in both previously trained and sedentary populations. Overall, CRT could be recommended to a range of populations to provide improvements to body composition and overall improvements in health and fitness while allowing for a smaller time commitment than typical resistance training or running endurance programs.

Overall, CRT has been shown to provide significant improvements to components of physical health and fitness. High-volume CRT has been shown to significantly increase VO_{2max}, although the improvements observed can be significantly lower than traditional aerobic endurance training. There is also a non-linear relationship between HR and VO_2 with CRT due to the increased use of upper body muscles, which could explain the smaller magnitude of improvement compared to typical aerobic endurance programs which typically utilize the large muscles of the legs. Additionally, significant improvements to VO_{2max} have also been observed in HRC when compared to TS. Along with improvements in VO_2, increases in EE significant enough for weight loss without dietary changes have been observed with CRT. Improvements associated with CRT are not only limited to aerobic performance, but also muscular strength and endurance and body composition. Strength and endurance have been shown to significantly increase consequent to CRT with strength gains being comparable to TS when heavy loads are used. The improvements in strength and endurance have been shown to occur with significantly less training time. Significant improvements in body composition have also been observed with CRT. Improvements in body composition have been shown to occur regardless of whether CRT is implemented alone, alongside running, or during HRC training and independent of rest intervals utilized. Observed improvements in VO_2, muscular strength and endurance, and body composition have been shown to occur regardless of training status or sedentary lifestyle. Additionally, improvements to muscular strength and endurance and body composition are repeatedly observed to occur with significantly less training time than typical endurance training or strength training. Given the significantly smaller time requirements coupled with significant improvements to components of physical health and fitness, CRT could prove to effectively address time as a perceived barrier to exercise.

Physiological Adaptations to HIIT

High-intensity interval training shares similar fundamental principles in exercise implementation as CRT. Similarities between the two training modalities exist in the use of repeated bouts of activity with minimal rest between bouts. Whereas CRT generally involves rest periods between exercises targeting separate muscle groups of 30s-1m, HIIT typically involves repeated bouts of the same activity (run sprints, cycle sprint, etc.) for brief periods (10s – 5m) at an intensity of 85-90% VO_{2peak} or 90-95% HR_{peak} with recovery periods of inactivity or low-intensity activity that allow for partial, but not full recovery (Gibala, Little, MacDonald, & Hawley, 2012; Gibala & McGee, 2008; Kessler, Sisson, & Short, 2012; Laursen & Jenkins, 2002; Wisloff, Ellingsen, & Kemi, 2009). Additionally, HIIT typically involves aerobic training such as running, swimming, or cycling rather than resistance exercises. However, as the definition of HIIT allows for classification by achieving a specific threshold of HR_{peak}, HIIT could be applied to resistance training in a typical circuit format. Current literature primarily investigates the effects of HIIT on measures of aerobic power, anaerobic power, and body composition. Consequent to the high intensities of exercise required by HIIT, participants in studies examining this training mode are typically previously trained or athletes, though some observations of training adaptations in sedentary samples also exist.

Aerobic power. High-intensity interval training is typically implemented through aerobic training modes such as running, swimming, and cycling. Given the typically aerobic nature of HIIT as a training protocol, one of the primary physiological alterations examined by researchers is VO_{2max} or VO_{2peak}.

Siahkouhian, Khodadadi, and Shahmoradi (2013) examined HIIT in 12 healthy, inactive male university students (age = 19.4 ± 1 years) and 12 male collegiate soccer players (age = 19.4 ± 1 years). One of the primary variables examined within this study was the effect of HIIT on aerobic indices. Training was similar for both groups of participants, including a 6 min warm-up, and 6-10 bouts of 30 sec maximal-effort sprints. Each of the 6-10 intervals was separated by a 4m passive recovery period and following the conclusion of all interval bouts, a 5 min cool-down period was conducted. The overall duration of training was 8 weeks. Siahkouhian et al. (2013) observed a significant increase in VO_{2max} in both the active (7.6 ± 2.1%) and inactive group (13.7 ± 4.9%). However, the inactive group demonstrated a significantly ($p < .05$) larger increase in VO_{2max} than the active group. The significant difference of VO_{2max} improvement between the two groups could likely be attributed to the lower baseline VO_{2max} of the inactive group allowing for greater overall improvements in relation to proximity to participant maximal possible conditioning values. Additionally, it is unclear whether significant changes would be observed in collegiate soccer players during the training season, as this study was conducted in the off season. It is possible that results for this group would show a lesser degree of improvement during the training season. However, these data indicate that HIIT can significantly improve VO_{2max} in both collegiate athletes and inactive populations of health young adults.

In addition to trained athletes and inactive samples, understanding the effects of HIIT in sedentary samples, as well as intensities and rest durations tolerable in these samples, could provide an understanding of the possible benefits to components of physical fitness in a sedentary population. Tong et al. (2011) examined the effects of a leg-cycle ergometer HIIT training protocol on sedentary, obese adults. Participants in this study were men (n = 4) and women (n = 12). Participants were assigned randomly into an interval training group (IT) or IT plus proportional-assist ventilation group (PAV, IT+PAV). However, for the purposes of this review of literature, only the results from the IT group are relevant. Training consisted of a 6 week HIIT training program with three training sessions per week. Each training session consisted of 20 x 30-second bouts of leg cycling at 120% peak work rate (W_{peak}) with 60 sec recovery periods at 20 W separating each exercise bout. Results indicated a significant increase ($p < .05$) in VO_{2peak} (Pre = 36.2 ± 5.8; Post = 38.6 ± 5.0 mL·kg^{-1}·min^{-1}), representing a 7% improvement in VO_{2peak}. These data indicate that, at a lower workload than a typical Wingate-based HIIT program, positive adaptations in aerobic capacity can be achieved in sedentary and obese individuals. Similarly, Drigny et al. (2012) observed significant improvements in VO_{2max} with middle-aged (49.4 ± 8.7 years), overweight adults consequent to a 4 month HIIT program with two HIIT sessions per week and two resistance training sessions per week.

Bayati, Farzad, Gharakhanlou, and Agha-Alinejad (2011) investigated the effects of a low-volume HIIT program. Participants were 24 male graduate students (age = 25 ± .8 years) who were habitually active but were not engaged in any formal structured training program for at least 3 months prior to testing. For the training intervention, participants were assigned to 1 of 3 groups: (G_1) 30s sprints at maximal-effort with 4min recovery; (G_2) 30s sprint at 125% of P_{max} (W, power at VO_{2max}) with a 2 min recovery; and a control group. Training group sprint training was conducted on a leg-cycle ergometer. The G_1 group performed three intervals per session in week 1, five intervals in week 3, and four intervals in week 4; the G_2 group performed double the number of intervals as G_1 on all weeks. Total duration of the intervention was 4 weeks, however, the authors did not note how many training sessions were conducted per week. The G_1 and G_2 groups both significantly ($p < .05$) increased VO_{2max} from pre- to post-testing, however, neither group had significant improvements when compared to the control group. Also, P_{max} and T_{max} (s, time to exhaustion at P_{max}) demonstrated significant improvements in G_1 and G_2 pre- to post-testing and when compared with the control group. Overall, results indicated that, with a Wingate-based HIIT protocol, both an all-out sprint (G_1) and a lower-intensity (G_2) HIIT program can achieve similar results in VO_{2max} improvements (G_1: 9.6% and G_2: 9.7%) in an untrained sample. Similarly, both groups also demonstrated a marked (G_1: 48% and G_2: 54%) increase in T_{max}, demonstrating a possibly increased use of aerobic metabolism or decreased lactate accumulation. However, Bayati et al. (2011) noted that this type of training requires specialized equipment as well as a high degree of participant motivation due to the extreme nature of the exercise intensities used. As such, the author's speculated that this type of training would not likely be tolerated by the general population. It could be of use to investigate the development of a modified HIIT protocol that would be more readily tolerated by the general population.

Rowan, Kueffner, and Stasinos (2012) conducted an investigation using a similar level of intensity and volume of training with similar rest intervals as the G_1 group in Bayati et al.'s (2011) study. Rather than an untrained population, Rowan et al. recruited 11 female collegiate soccer players (age = 19.5 ± .93 years). Participants were matched by VO_{2max} and randomly assigned to either an endurance (END) or sprint training (SPR) group. The training intervention spanned 5 weeks with both groups training two times per week. Training for the SPR group consisted of five repetitions of 30 sec maximal effort sprints separated by 4.5 min active recovery (jogging) for 25 min. Due to improvements in participant aerobic capacity, recovery intervals were reduced to 3.5 min during the 4th week. The END group performed 40 min of running at 80% VO_{2max}. Results indicated no significant difference in VO_{2max} between groups pre- or post-tests. However, both training groups did show significant improvements in VO_{2max} from pre- to post-tests. These results indicate that HIIT elicits similar significant aerobic improvements as traditional endurance training in approximately half the training time in previously trained athletes. Therefore, HIIT could be a viable alternative to traditional endurance training in previously trained athletes or well-trained populations for the increase of VO_{2max}, especially in those who perceive time as a significant barrier to exercise.

Rather than use a percentage of VO_{2max} or P_{max} to determine exercise intensity, Dufield, Edge, and Bishop (2006) used lactate threshold (LT) to determine HIIT exercise intensity. Physically active females ($n = 10$; age = 20 ± 4 years) participated in 8 weeks of periodized HIIT 3 days per week. Training intensity was set at a percentage of LT: 130% (week 1), 140% (week 2), 150% (weeks 3 and 4), 160% (week 5), 170-180% (weeks 6 and 7), and 170% (week 8). The number of intervals utilized varied between each day of training and each week; interval duration was 2 minutes with an inactive recovery period of 1 minute between each interval. All training was done on a mechanically braked leg-cycle ergometer. Dufield et al. observed a significant ($p < .05$) increase in VO_{2max} from pre- to post-training. Additionally, both power at VO_{2peak} and power at LT increased significantly. There was also a significant decrease in the anaerobic metabolism contribution following training. Overall, the results indicate that a severe-intensity HIIT training protocol can increase VO_{2max} at maximal exercises intensities while not slowing the speed of aerobic exercise response and reducing reliance on anaerobic metabolism during high-intensity exercise.

High-intensity interval training has also been observed to elicit significant improvements in children and special populations. Sperlich et al. (2010) examined HIIT swimming on VO_{2peak} and competition performance in 9-11 year-old swimmers. A component of the justification for use of HIIT in 9-11 year-old swimmers was established as a time-saving training program that would allow for the development of other skills or limitations due to school scheduling and other free-time activities. A crossover study design was utilized for this study; each participant performed both a 2 x 5-week HIIT training period and a high-volume training (HVT) period. Group crossover was initiated following a 6 week summer break with groups classified as either A or B depending on which training was conducted first. Participants (n = 26; 13 male, 13 female) participated in five training sessions per week in a 50 meter outdoor pool.

Differences in training between the HIIT and HVT groups were in duration (30 min vs. 60 min, respectively) and intensity of personal best time for each distance (92% and 85%, respectively). Following training, total volume for the training groups was 5.5 km per week for HIIT and 11.9 km per week for HVT. Consequent to HIIT, there was significant increase in VO_{2peak} ($p < .01$) for A and B combined, with significant increases observed in A ($p < .01$) and B ($p < .05$) individually. The HVT group also demonstrated a significant total increase in VO_{2peak} ($p < .01$), however, only the A group demonstrated a significant improvement ($p < .01$). Additionally, there was an overall significant improvement ($p = .04$) observed in 2,000 meter swim time consequent to the HIIT. Of particular importance for this study is that these results were achieved with significantly less training time and training volume in HIIT as with HVT. These results further support HIIT as a time-efficient alternative for eliciting improvements in aerobic capacity similar to traditional high-volume endurance training. This evidence is further strengthened by the use of a different training mode (swimming *vs.* the traditional leg cycling or sprinting) and the use of a non-adult sample. Results from this study suggest that HIIT is an effective and time-efficient method of training across modes and exercise and populations.

Terada et al. (2012) examined the effects of HIIT in a sample of men and women (age = 55-75 years) who had type 2 diabetes. Terada et al. compared HIIT with moderate intensity continuous exercise (MICE). Though the primary purpose of the study was to examine recruitment, adherence, and retention of the two types of training in this sample, secondary measures included VO_{2peak}. Intervention training was conducted 5 days per week for 12 weeks with exercise duration, frequency, and average relative intensity (VO_2R) matched between training groups. The MICE group exercised at 40% VO_2R during each session while the HIIT group performed 1 min intervals at 100% VO_2R with 3 min recovery periods at 20% VO_2R for an average of 40% VO_2R over the duration of the session. The HIIT performed as many complete intervals as possible during the 30 min training period, with the remaining time spent at 40% VO_2R. Exercise sessions were progressive and increased from 30 min per session in weeks 1-4 to 45 min sessions in weeks 5-8 and 60 min per sessions for weeks 9-12. The mode of exercise varied between cycling and treadmill walking to allow for exercise variety.

Results for alterations in VO_{2peak} were not significant for either group, however, O_2 consumption at VT increased significantly (p = .025) for both groups. Additionally, maximal power output (W) during VO_{2peak} testing was increased significantly (p = .029) only in the HIIT group. Although the results did not support significant improvements in VO_{2peak} for either group, VT did increase significantly which indicates that the training was effective at improving aerobic fitness. Additionally, the magnitude of change in VO_{2peak} was greater in HIIT compared to MICE, despite not being a significant increase.

In is unclear why the magnitude of improvement in VO_{2peak} was not significant in this sample, although it could be due to the advanced age of the participants involved. Regardless, results demonstrated positive alterations to VO_{2peak} and O_2 consumption at VT in this sample, supporting HIIT as a viable mode of training in both older populations and in those with disease. Additionally, while HIIT typically involves supramaximal intensities of exercise which are generally regarded as intolerable for untrained populations, this study provides evidence that with a properly modified HIIT program, special populations can also benefit from this type of training with no detriments to recruitment, retention, or exercise adherence.

Overall, HIIT has been demonstrated to elicit significant improvements in VO_{2max} in approximately half the training time and training volume as traditional high-volume endurance training, similar to results observed with CRT. It is also of interest to note that these changes are evident across various samples and exercise modalities utilized. Current literature would, therefore, appear to support HIIT as a viable and time-efficient alternative to traditional endurance training for the improvement of aerobic power.

Anaerobic power. Due to HIIT typically involving short-duration bouts of supramaximal exercise intensities, examinations of improvement in anaerobic power are common. While HIIT is often examined for its time-efficient improvements to aerobic power, the short-duration high intensity bouts of exercise utilized in HIIT also allow large contributions of the anaerobic pathways during exercise. Anaerobic power is typically measured with a 30 sec Wingate Anaerobic Power Test and expressed with both peak power output (PP, highest work output in 5 s period) and MP, average work output during 30 sec test period, as mean ± standard deviation in Watts.

In an investigation of HIIT sprint training on performance and metabolic adaptations, Bayati et al. (2011) examined changes in anaerobic power consequent to the intervention in physically active male graduate students. As a result of 4 weeks of training, significant changes in anaerobic power were mostly evident only in G_1, which performed 30 sec bouts of maximal effort cycling with 4 min of recovery between bouts. In this group, PP ($p = .006$) and MP ($p = .025$), were significantly greater than the control group post-test and significantly increased from pre- to post-test. The G_2 group only showed significant improvements in PP ($p = .04$) with no significant changes in MP ($p = .06$) from pre- to post-test and no significant changes when compared to the control group post-test. These results provide evidence that HIIT can significantly improve anaerobic power when utilized as maximal effort bouts of exercise.

Utilizing similar training intensities as found in Bayati et al.'s (2011) G_1 group, Siahkouhain et al. (2012) compared adaptations to anaerobic power consequent to HIIT in a sample of active adult male soccer players in their off season (active) and physically inactive male college students (inactive). Both groups demonstrated significant increases in PP and MP (active, $p < .001$; inactive, $p < .001$) from pre- to post-test. Additionally, the inactive group demonstrated significantly greater improvements ($p < .05$) compared to the active group in both PP and MP. While these results are not surprising, given the greater possible maximal threshold for improvement in the inactive sample, the results further indicate maximal-effort HIIT training can induce significant improvements in both inactive and active, previously trained samples. The significant increase in anaerobic power in the active sample consequent to HIIT could be of particular interest to athletic coaches for further improvements in athletic performance.

Current literature provides evidence that HIIT is capable of significantly increasing anaerobic power in both inactive samples and active, collegiate level athletes. However, it is of interest to note that these adaptations are likely a factor of intensity. As demonstrated by Bayati et al. (2011), HIIT that is not of a maximal-effort intensity (G_2) does not provide similar significant improvements to factors of anaerobic power as maximal-effort bouts of exercise. However, with maximal-effort exercise bouts (Bayati et al., 2011; Siahkouhan et al., 2012) significant improvements were observed in PPO and MPO in both collegiate athletes and physically inactive samples. Indeed, in a review of the literature, Gibala et al. (2012) also stated that supramaximal effort work bouts of short duration are effective at improving performance. Additionally, it is of interest to note that these improvements in anaerobic power are consistent with a greater reliance on glycolysis (Bayati et al., 2011) during short-duration, maximal-effort exercise while simultaneously decreasing the contribution of anaerobic metabolism during a graded exercise test (Dufield et al., 2006).

Body composition. As with CRT, consequent to the high intensity exercise and large aerobic contribution utilized, HIIT possesses a large potential for the improvement of body composition. High intensity interval training has been shown to elicit significant improvements to body composition in adults with type 2 diabetes and healthy, sedentary adults. However, literature examining HIIT is primarily focused on adaptations to anaerobic and aerobic power with body composition alterations being examined less frequently.

In older adults (age = 55 – 75 years) with type 2 diabetes, Terada et al. (2012) observed significant improvements in body composition with HIIT training. In this study, the HIIT group demonstrated a significant decrease in total %BF ($p = .009$), % trunk fat ($p = .007$), and % leg fat ($p = .032$). Despite the exercise being matched for overall relative intensity, the HIIT group was observed to have a greater magnitude of change on these measures of body fat than the MICE group. Significant decreases in %BF, particularly in the trunk, are particularly desirable in this sample because excess body fat in the trunk region is associated with type 2 diabetes as well as increased risk for other diseases.

Similar results in body composition improvement were observed by Tong et al. (2011) in sedentary, obese adults who were otherwise healthy. With a 6 week non-Wingate based HIIT protocol, %BF decreased significantly ($p < .05$) from 31.3% ± 5.7 to 29.1% ± 5.6. These significant improvements are noteworthy because they were achieved with an intensity of exercise which was lower than the typical supramaximal effort utilized in most HIIT protocols. Additionally, this study demonstrated that a decreased intensity of exercise implemented in a HIIT format can be tolerated in obese adults and still induce significant improvements in body composition.

Although alterations to body composition with HIIT are less often examined than with CRT, there have been significant improvements observed in %BF in different populations. The significant decreases in total %BF as well as %trunk fat in older adults with type 2 diabetes are particularly noteworthy because of the increased risk for disease and symptoms of type 2 diabetes with excess trunk fat and overall body fat. Additionally, the significant decreases in %BF observed in health adults with obesity are also noteworthy because HIIT can provide significant improvements to body composition and decrease the risk for disease during a shorter training period than typical mild-intensity, continuous exercise. Further review of the literature would be required to make statements on the efficacy of HIIT for alteration of %BF in more active samples. However, the observed improvements in body composition with HIIT demonstrate that it is an effective method of training for decreasing disease risk and can be tolerated by older adults with existing disease conditions and mild obese healthy adults.

High-intensity interval training has typically been utilized via supra-maximal training intensities. However, a number of studies have demonstrated that HIIT of both supra-maximal and sub-maximal intensities can produce significant improvements in VO_{2max}, PP, MP, and %BF, in significantly less time and training volume as traditional high-volume sub-maximal endurance training. Additionally, these adaptations are evident independent of intensity measures (%VO_{2max}, speed, or LT); in untrained and trained adults; trained adolescent competitive swimmers; older adults with type 2 diabetes; obese adults; and independent of training modality utilized (leg cycle ergometer, sprinting, or swimming). Although HIIT typically involves more aerobic modes of exercise focusing on the large muscles of the lower body, examining the effects of total body resistance HIIT could provide similarly significant results while improving total body lean muscle mass.

P90x® Home Exercise Program

Home exercise programs offer a unique opportunity to address many of the perceived barriers to exercise experienced by many individuals. Additionally, with the proper utilization of body weight resistance as well as minimal resistance equipment in a CRT or HIIT format, home exercise could simultaneously elicit significant improvements in muscular strength and endurance, aerobic power, anaerobic power, and body composition. P90x® is a DVD-based home exercise program that utilizes components of CRT and HIIT to provide constantly evolving, high intensity exercise. However, there is little literature examining this program available. In fact, there has been only one study conducted examining P90x®.

In one unpublished thesis (Woldt, 2011), the energy cost of 4 of the 12 P90x® workouts was examined. Woldt found average HR value for males was between 67-83% of maximum HR (HR_{max}) and between 65-88% HR_{max} for females, while VO_2 values were between 45-70% and 45-80% of estimated VO_{2max}, respectively. There were, however, notable limitations in this study. Values for O_2 consumption were obtained by measuring participant VO_{2max} through a treadmill protocol and creating individual HR/VO_2 regression equations for each participant rather than measuring the O_2 cost of the P90x exercises through indirect calorimetry. Estimating O_2 consumption through regression formulas is inherently less accurate than a direct measure and could, therefore, provide significantly different VO_2 values than would otherwise be observed. However, a direct measure of O_2 consumption during a typical P90x® workout would be problematic, even with a portable O_2 analyzer, due to the bulk and intrusive nature of the devices and the amount of movement occurring during a typical P90x® workout. Woldt also established levels of EE with the four workouts used, however, as these EE values were also derived from estimated VO_2 levels, these values could also be inaccurate. The study was similarly limited by a relatively small sample size (n = 16). Additionally, it is unclear whether the four P90x® workouts chosen accurately represent the entirety of the P90x® program. Despite the limitations of this study, results supported P90x® as a viable option to meet the recommended guidelines for physical activity or exercise in terms of intensity and EE.

Summary of the Literature

The need for exercise and physical activity has been well established. However, despite publication of minimal recommendations for health and fitness improvement, nearly half of U. S. adults meet neither the minimal recommendations for muscular strength training nor the minimal recommendations for aerobic training. Perceived barriers to exercise such as time, lack of access to facilities, lack of an exercise partner, and financial cost could greatly affect the prevalence of exercise and physical activity in U.S. adults.

Training programs such as CRT and HIIT have been shown to significantly improve VO_{2max}, muscular strength and endurance, body composition, anaerobic power, and increase overall EE across samples. These adaptations are evident across both sedentary and highly trained samples and are typically achieved in significantly less training time than traditional strength or endurance training protocols. DVD-based home exercise programs also present a potential method to decrease the frequency and strength of reported barriers to exercise. P90x® is a highly marketed and popular DVD-based exercise program in the U.S. This training programs utilizes CRT and/or HIIT. However, despite the popularity and wide-spread use of this program, there is little available literature examining its potential effects on fitness. The one available piece of literature examining P90x® investigated the VO_2 cost of four of the P90x® workouts. There is currently no available literature on P90x® regarding the effects of muscular strength or endurance, body composition, or anaerobic power. Therefore, the purpose of this study is to perform a pre- and post-training analysis on changes to upper and lower body muscular strength and endurance, body composition, and anaerobic power after 4 weeks of training.

CHAPTER III

METHODOLOGY

Participants

Healthy, adult male and female participants (*N* = 18) were recruited from the student body at a university, and the community, in the southeastern United States. The number of participants recruited was smaller than the desired sample size of 30 due to the availability of participants for scheduled training times and frequency. Healthy adults were categorized as those of low to moderate risk according to American College of Sports Medicine guidelines (2014) based on information obtained from a distributed health history questionnaire. Maximum sample size was approximately 100 participants. Participant inclusion criteria required involvement in chronic, structured exercise for at least the previous 6 months, no health conditions that would interfere with training, and personal transportation to and from the testing and training facilities.

Instrumentation

Health history. Participants completed a health history questionnaire (Premier Performance, Inc., 1996). The information gathered from the health history questionnaire was used to perform risk stratification on all participants and ensure there were no contraindications to vigorous exercise.

Body mass and height. Body mass was measured using a digital scale (BF-522W, Tanita, Tokyo, Japan). Body mass was measured in kilograms to the nearest 0.1kg in exercise clothing without socks or shoes. Height was obtained using a telescopic stadiometer (Seca 222, Seca GMBH & Co. Kg.). Height was measured without shoes or socks to the nearest 0.1cm. The same scale and stadiometer were used for all participants.

Body composition. Body composition measures were taken using a seven-site skin fold test according to the procedures described by American College of Sports Medicine (2014) and reported as %BF. Calibrated Lange skin-fold calipers (Cambridge Scientific Industries, Cambridge, Md.) were used to measure skinfolds. Skinfold measurements were taken on all participants using the same calipers by the same investigator. Skinfold measurements were converted to body density (Db) using the corresponding seven-site equations for males and females (American College of Sports Medicine, 2014; Jackson & Pollock, 1985). Skinfolds were taken a minimum of two times on the right side of the body, or until a measure was obtained within 1mm of the previous measure. The two recorded measures were averaged at each site and applied to the appropriate Db equation. Body density was then converted to %BF based on race and sex appropriate equations (American College of Sports Medicine, 2014; Heyward & Stolaryczyk, 1996).

Upper body measures. A standard 45lb Olympic barbell, weights, collars, and bench were used to test for upper body muscular strength and endurance. Upper body muscular strength was measured as 1RM bench press according to standardized procedures (American College of Sports Medicine, 2014). A successful measure of 1RM required achievement of a maximal lift within five attempts. To standardize movements among participants, a standard bench press required the upper arm to be, at a minimum, parallel with the walking surface at the lowest lifting position; for the upward lift, the top of the movement was required to end just prior to elbow lockout. A full repetition was counted as a controlled movement to the down position and back to the top position, without bouncing the bar off of the chest. Failure to maintain form as instructed resulted in termination of the test to provide additional instruction of technique as required.

Upper body muscular endurance was measured relative to 50% of each participant's pre-training 1RM value and logged as maximal number of repetitions completed at a rate of 60 beats per minute, or 1-sec for the downward movement and 1-sec for the upward movement. Muscular endurance for the upper body was tested with the bench press utilizing the same equipment and movements as used for the 1RM bench press.

Lower body measures. A counter-balanced Smith Machine (Pro-Elite Strength Systems, Item Number 52A, Salt Lake City, Utah, U.S.A) was used to conduct lower body measures of strength and endurance. Due to the counter-balanced design of the Smith machine, the initial starting weight was 9.09 kg rather than the standard 20.45 kg of an Olympic barbell. Lower body strength and endurance were measured with a back squat. The back squat was performed according to previously established standards (National Strength and Conditioning Association, 2008). Lower body strength testing was measured as 1RM according to the same procedures as used for upper body strength testing. Lower body muscular endurance was also measured as the maximal number of repetitions performed with a back squat with weight relative to 50% of each participant's 1RM value at a rate of 45 beats per minute, or 1.3-sec for the downward movement and 1.3-sec for the upward movement.

Anaerobic power. A mechanically braked bicycle ergometer (Ergomedic 894E Peak Bike, Monark Sports and Medical, Vansbro, Sweden) was used to measure anaerobic power. Pedal revolutions were recorded utilizing manufacturer supplied software. Anaerobic power was measured using the Wingate Anaerobic Test (WAnT). Measures of anaerobic power were logged as mean anaerobic power (MP) relative to participant body mass. Validity, reliability, and methodology of the Wingate protocol has been previously established (Bar-Or, 1987; Inbar, Bar-Or, & Skinner, 1996). Participants were given a 5 minute warm-up period prior to the test with alternating periods of all-out speeds with minimal resistance for 5-10s, 30s light-moderate speeds with minimal resistance, and 30s rest. Following the warm-up, a 3-5 minute rest period was given to minimize any fatigue associated with the warm-up procedure. Participants were instructed to pedal as fast as possible against a low resistance and, when the participant had achieved his or her maximal pedal rate, a participant-operated button released the full predetermined load (.075 kp per kg body mass) to the flywheel. The participant then pedaled at a maximal rate for the duration of the 30s test. Count of pedal revolutions began immediately upon load release and were counted the entirety of the 30-sec test. A 2-3-min cool-down period of pedaling against a light resistance followed the 30-sec testing procedure to minimize the risk of dizziness and syncope.

Procedures

This study, before initiation of any data collection, was approved by the Institutional Review Board (IRB) at the University (see Appendix A). On arrival at the testing facility during the first testing session, participants were asked to read and sign a written informed consent form (see Appendix B), which was observed by the researcher; full disclosure of the training program and expectations, risks, and benefits were also verbally explained. Risk stratification was conducted on each participant through a health history questionnaire. Participant attendance was recorded to obtain a measure of adherence; participant attendance criteria was set at 80% or greater. Any participant falling below 80% attendance was permitted to continue with the program, however, exercise test data collected from participants failing to meet adherence criteria were excluded from data analyses. Participants were instructed to wear comfortable athletic clothing and closed-toe exercise shoes to ensure similar exercise conditions for all participants.

All participants were assessed for LS and LE, US and UE, MP, and %BF immediately before training and immediately after 4 weeks of training. All strength measures and MP were recorded relative to body mass. Participants were advised to continue their normal daily routine and maintain normal dietary habits.

Body mass, height, and body composition measures were taken on the first test session. Order of test sessions were random, with MP testing occurring on its own day, with at least one full day between test sessions. Upper and lower body muscular strength and endurance were tested on the same day. At least 10 minutes were allotted for each participant between muscular strength and endurance testing of the same region to allow for sufficient recovery. For upper limb and lower limb 1RM testing, failure to achieve a maximal lift within 5 attempts resulted in rescheduling of the test to a date no sooner than 2 days following the previous testing session. For muscular strength and endurance testing, participants were spotted at all times. Measures of body mass, LS, LE, US, UE, lower body MP, and %BF were taken both pre- and post-intervention.

Training was established in a manner that the researcher deemed to best represent the P90x® program as a whole. In order to approximate an intensity and duration that was representative of the entirety of the P90x® program, exercises were selected from Phase

2 (weeks 5-8) of the P90x® Classic program. The actual training schedule is represented in Table 1.

The intervention consisted of training for a minimum of 4 days per week for 4 weeks with two rest days per week. The 80% attendance criteria allowed for 1 missed session per week with the option of a make-up date on the Saturday of each week. Training sessions were conducted in a group format with one training block per day. All training sessions were supervised by a certified personal trainer with current cardiopulmonary resuscitation (CPR), First Aid, and automated electronic defibrillator (AED) certifications. Training was conducted in a large, open floor room in a group-exercise environment using the appropriate program DVDs. Participants were instructed to give maximal effort to keep pace with the video-led training. Dumbbells, pull-up bars, and resistance bands were available for use if the exercises in the training program necessitated them. Where resistance was used, participants were instructed to self-select a resistance that would allow for 8-12 repetitions. Resistance was increased as needed when repetitions performed exceeded 12.

Data Analysis

Data were analyzed using IBM Statistical Package for the Social Sciences (SPSS) 20 for Windows (IBM Corp., Armonk, NY). A repeated measures multivariate analysis of variance (MANOVA) was performed on 6 variables to compare changes over time. Muscular strength and MP values were recorded relative to body mass in kg. Descriptive data were presented as mean (± standard deviation) *M* (± *SD*). Statistical significance was accepted at an alpha level of < .05.

Table 1

P90x Schedule

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Week 1	Chest, Shoulders, & Triceps; Ab Ripper X (71.85 min)	Plyometrics (58.6 min)	Back & Biceps; Ab Ripper X (67.72 min)	X Stretch (57.53 min)	Legs & Back; Ab Ripper X (75.05 min)	Rest	Rest
Week 2	Chest, Shoulders, & Triceps; Ab Ripper X (71.85 min)	Plyometrics (58.6 min)	Back & Biceps; Ab Ripper X (67.72 min)	X Stretch (57.53 min)	Legs & Back; Ab Ripper X (75.05 min)	Rest	Rest
Week 3	Chest, Shoulders, & Triceps; Ab Ripper X (71.85 min)	Plyometrics (58.6 min)	Back & Biceps; Ab Ripper X (67.72 min)	X Stretch (57.53 min)	Legs & Back; Ab Ripper X (75.05 min)	Rest	Rest
Week 4	Chest, Shoulders, & Triceps; Ab Ripper X (71.85 min)	Plyometrics (58.6 min)	Back & Biceps; Ab Ripper X (67.72 min)	X Stretch (57.53 min)	Legs & Back; Ab Ripper X (75.05 min)	Rest	Rest

CHAPTER IV

RESULTS

Male (n = 4) and female (n = 9) adults aged 24.4 years (± 4.0) participated in this study. Of the 18 participants who began the study, 1 did not complete pre-intervention testing and 4 did not meet the 80% adherence criteria across the duration of the intervention, resulting in a final sample of 13 participants. The mean height of the sample was 167.6 cm (± 5.6) and pre-intervention mean body mass was 68.8 kg (± 11.6). Body mass showed no significant change from pre- to post-intervention (68.6 kg ± 12.1).

A one-way repeated measures MANOVA with univariate follow-ups was used to determine overall significance of changes across the intervention. Training was related to the change in the dependent variables, Wilks' F (1, 5) = 7.37, p = .022, η^2 = .898. Univariate follow-ups (Greenhouse-Geisser) were used to determine which dependent variables experienced significant change over time. Significant improvements were observed in US, LS, UE, LE, and %BF from pre- to post-intervention; no significant change was observed in MP (see Table 2). There was no significant change in the power variable.

Table 2

Change Over Time in Measures of Physical Fitness as a Result of P90x® Intervention

Dependent variable	*F*	*p*	η^2	*M* ± *SD*
Upper strength	5.87*	.036	.37	
Pre				.72 ± 0.35
Post				.76 ± 0.38
Upper endurance (#reps)	15.8*	.003	.61	
Pre				25 ± 4
Post				30 ± 4
Lower strength	37.65*	< .001	.79	
Pre				1.22 ± 0.39
Post				1.32 ± 0.40
Lower endurance (#reps)	13.16*	.005	.57	
Pre				23 ± 10
Post				31 ± 13
Mean power ($W \cdot kg^{-1}$)	2.35	.16	.19	
Pre				5.79 ± 1.11
Post				6.23 ± 1.22
Body composition (%BF)	14.12*	.004	.59	
Pre				20.3 ± 6.8
Post				18.7 ± 6.8

Note. * = Significant difference pre-post, $p < .05$; $df = (1, 10)$ for each one-way repeated measures ANOVA; Strength values are reported as kg lifted relative to body mass in kg; #reps = total number of repetitions performed; %BF = percentage body fat.

CHAPTER V

DISCUSSION

P90x® is a DVD-based home fitness program that is designed on principles of CRT and HIIT. Home-based fitness, as well as CRT and HIIT training protocols, are of interest due to the generally shorter duration of training times in addressing lack of time as a perceived barrier to exercise as well as the ability of CRT and HIIT to provide muscular strength and endurance improvements and significant changes in body composition while simultaneously maintaining a moderate aerobic component. With high obesity rates in both adults and children and nearly half of the adult population over 18 years of age in the United States reported as meeting neither the minimum recommendations for aerobic activity nor the minimum recommendations for muscle strengthening activity, P90x® offers a unique opportunity to appeal to populations where time is the main limiting factor in participation of exercise.

The purpose of this study was to investigate the effects of a 4 week P90x® training intervention on markers of physical fitness. Upper and lower body muscular strength relative to participant body mass, upper and lower body muscular endurance, anaerobic power relative to participant body mass, and body composition were examined as primary dependent variables. To approximate average intensity representative of the entirety of the P90x® program in a 4 week intervention, this study utilized exercise DVDs from the middle of the program. The exercise DVDs were selected to ensure all muscle groups were trained while also including stretching and plyometric activity.

Rather than 6 days of training per week as is established with the true P90x® training program, this study utilized a 5 day per week training protocol in order to facilitate participant adherence. Additionally, while the true P90x® program allows participants to select resistances for a desired repetition range based on goals for endurance, mass, or strength, for the purposes of this study participants were instructed to self-select resistances that would allow for 8-10 repetitions on each exercise that utilized resistance equipment. The 8-10 repetition range was selected in order to allow for both strength, endurance training, as well to ensure an elevated HR was maintained.

Muscular Strength

Muscular strength is often defined as the ability of skeletal muscle to exert maximal or near maximal force against an external object. Improvement and maintenance of muscular strength can make typical activities of daily living (ADL) easier to perform. This investigation included a 1RM lift to determine maximal muscular strength in kg relative to body mass in kg. Upper limb strength was measured with a standard barbell bench press while lower limb strength was measured with a half squat with a counter-balanced Smith Machine (Pro-Elite Strength Systems, Item Number 52A, Salt Lake City, Utah, U.S.A).

Upper body 1RM values changed significantly ($p = .036$) from pre- (.72 kg ± .35) to post-intervention (.76 kg ± .38), an improvement in strength of 5.6%. Lower limb 1RM also significantly increased ($p < .001$) from pre- (1.22 kg ± .39) to post-intervention (1.32 kg ± .40), an increase in strength of 8.2%. These results support the hypothesis that 4 weeks of P90x® training would significantly increase muscular strength. The greater improvement in lower limb muscular strength may be attributed to the inclusion of both the Legs and Back and Plyometrics DVD, both of which have a large lower body component, for a combined duration of 116.9 min per 5 days. In contrast, only one DVD targeting the chest and triceps region was included in the intervention for a total weekly training volume of 55.4 min. It is, therefore, likely that these differences are due to the volume of lower body training being more than twice as much as chest and triceps training.

While these improvements support previous research on the strength benefits of CRT, the percentage of improvement (5.6 – 8.2%) compared to previous research (10.6 – 36.5%) is not as large. This is likely due to the shorter duration of this intervention compared to previous studies involving CRT that lasted 8 weeks (Alcaraz et al., 2011), 10 weeks (Harber et al., 2004; Wilmore et al., 1978), 12 weeks (Chtara et al., 2008; Gettman et al., 1982), and 20 weeks (Gettman et al., 1978). Further differences in the degree of strength improvement could be attributed to the resistance used during training. For this study, participants were instructed to self-select a weight that would allow for a maximum of 8-10 repetitions when resistance was used. Alcaraz et al. (2006) and Alcaraz et al. (2011) used resistances that allowed for only a 6RM which would also likely elicit greater strength improvement, even with a similar duration of intervention.

Despite the differences in total strength improvements between this intervention and previous studies, 4 weeks of P90x® training elicited significant improvements in both upper and lower body muscular strength with participants using an estimated, self-selected resistance of their individual 8-10RM. These results indicate that P90x® is an effective training program for the improvement of muscular strength when performed in the 8-10RM range.

Muscular Endurance

Muscular endurance is defined as the ability of muscle to sustain repeated contractions against a resistance for an extended period of time. In this investigation, muscular endurance was measured as the maximal number of repetitions performed against 50% of each participant's pre-intervention 1RM resistance. Upper body endurance significantly improved (p = .003) from pre- (25 ± 4) to post-intervention (30 ± 4), an increase of 20%. Lower limb endurance also significantly improved (p = .005) from pre- (23 ± 10) to post-intervention (31 ± 13), an increase of 34.8%. Similar to muscular strength, the differences in muscular endurance improvement between these two variables could be attributed to the difference in volume of training targeting the respective areas of the body.

These results support the hypothesis that P90x® would significantly improve muscular endurance over a 4 week training intervention. Although conducted using an 8-week training intervention, Arazi and Asad (2012) also found that, with a training program using an increasing %1RM resistance and decreasing reps over time, CRT significantly increased both bench press and leg press muscular endurance. These results are indicative of P90x® being an effective training method for improving muscular endurance. As with the results for strength improvement, the magnitude of change in muscular endurance could be attributed to the number of repetitions performed per exercise, the resistance used, the duration of total exercise, and amount of rest during the workouts.

Anaerobic Power

Anaerobic power is a measure of maximal power output during short-bout, maximal effort physical activity and is indicative of the energy-contribution of anaerobic energy pathways. Improvement in anaerobic power is beneficial for short-duration events lasting less than 2 minutes, such as sprinting, powerlifting, or sports involving jumping.

Results from this study indicated no significant change (p = .16) in MP from pre- (5.79 W·kg^{-1} ± 1.11) to post-intervention (6.23 W·kg^{-1} ± 1.22). However, previous research involving HIIT has elicited significant improvements in MP (Bayati et al., 2011; Gibala et al., 2012; Siahouhain et al., 2012). The lack of significant change in MP in this study could be due to the intensity of exercise involved in P90x®. Previous studies that have observed significant improvement in MP have typically utilized maximal or supra-maximal intensities in training with recovery periods between each bout. P90x®, due to the CRT components, does not allow frequent recovery between different types of exercise and, as a result, maximal or supra-maximal effort would not likely be sustainable in any of the training DVDs. The overall duration of activity in combination with submaximal intensities in P90x® likely provides a more aerobic training component than anaerobic and could potentially explain the lack of change in MP.

Body Composition

Excess body fat has been well established as a cause for increased risk of disease. Therefore, exercise programs that can effectively reduce body fat to healthier levels are of prime importance in the prevention of disease and maintenance of health and fitness. Circuit resistance training, the underlying principle upon which P90x® is based, has been effective at improving body composition in past research.

In the present study, 4 weeks of P90x® training significantly ($p = .004$) reduced %BF from pre- (20.3% ± 6.8) to post-intervention (18.7% ± 6.8). However, no significant change ($p > .05$) was observed in body mass from pre- (68.8 kg ± 11.6) to post-intervention (68.6 kg ± 12.1). The lack of change in body mass with a significant drop in %BF is indicative of a concurrent increase in lean body mass. These results support previous research providing evidence that CRT and HIIT, and subsequently P90x®, are effective at improving body composition (Alcaraz et al., 2011; Chtara et al., 2008; Ferraira et al., 2009; Gettman et al., 1982; Messier & Dill, 1985; Terada et al., 2012; Tong et al., 2011). It is of interest to note, however, that the changes observed in this study were achieved in less total intervention duration (4 weeks) than previous CRT studies have utilized. However, these changes are likely due to the overall volume and frequency of training required for the P90x® program being larger, 5 days per week in this study and 6 days per week for the true P90x® program, compared to previous CRT and HIIT research that has typically utilized a 3-day per week protocol and shorter training times. Additionally, the significant change in body composition observed in this study was achieved with no alteration to dietary habits. A diet plan is included with the P90x® program, however, a dietary control based on this plan was not utilized in this study. It is possible that results observed as a result of this training intervention could change with the inclusion of the P90x® dietary plan.

Overall Conclusions

The purpose of this study was to investigate whether P90x® could provide significant improvement in muscular strength and endurance, anaerobic power, and body composition in previously trained adults. Using one-way repeated measures MANOVA, it was determined that the training intervention was related to the change in the dependent variables. Univariate one-way ANOVAs, conducted as follow-ups, indicated that US, UE, LS, LE and %BF significantly improved over time. No significant change was detected in MP.

Attendance across the intervention was 80% during week 1, 88% during week 2, 84% during week 3, and 84% during week 4 for the first training group; attendance across the intervention was 95% during week 1, 90% during week 2, 90% during week 3, and 72.5% during week 4 for the second training group. Although the second training group only had a 72.5% attendance rate during week 4 of the intervention, due to high attendance during the first week, all participants were able to meet the overall 80% attendance criteria. Overall, participants who completed the study maintained an 85.8% attendance rate. Due to the large time commitment and 5 day per week training protocol, attendance adherence within a mainly university recruited population can be problematic. Numerous factors can affect attendance adherence in a study such as this, such as class schedules, work schedules, extra-curricular activities, exercise facility availability, and other factors which interfere with a defined daily schedule. Additionally, the frequency and intensity of the training involved in this study seemed to have an effect on attendance as the intervention progressed. Due to failure to maintain the attendance criteria, 3 participants were dropped from the study, and 1 participant was dropped due to a pre-existing injury.

The significant changes observed are likely attributed to the volume of training and the resistances used during training throughout the intervention. It is possible, however, that allowing participants to self-select resistances based on a repetition range could have affected the outcome. Due to the variation of the types of movements utilized, it was not feasible to determine each individual's resistance for a repetition range on each individual movement. Therefore, it is possible that some participants may have gone heavier or lighter than instructed and, subsequently, influenced individual changes in the dependent variables.

While the P90x® intervention utilized in this study did elicit significant improvements in markers of physical fitness, the ability of the program to address lack of time as a perceived barrier to exercise is tenuous. This training intervention used a total weekly training volume of 330.8 minutes with an average of 66.2 minutes per training day. The actual P90x® program utilizes a 6 day per week training calendar and includes exercise DVDs such as yoga, which are longer than those utilized in this study. As a result, the time commitment required for the P90x® program is larger than typically seen with CRT and HIIT training programs. However, with travel time to and from a fitness facility negated, it is possible that P90x® could potentially address time as a perceived barrier to exercise. Furthermore, P90x® could also address items reported as perceived barriers to exercise such as cost, a one-time purchase rather than a recurring facility membership or personal trainer, and lack of an exercise partner, due to a video-led exercise program offering motivation. Future research should be conducted to determine the minimal amount of training days required per week in order to gain benefits, which could also further address time as a perceived barrier to exercise.

The only limitation for recruitment in this study was meeting the desired age-range and having been involved in chronic exercise for at least 6 months prior to the initiation of the intervention. As a result, initial participant fitness levels were varied.

Future research should attempt to use a larger sample size, and more focused sample of either fit or unfit individuals, than was utilized in this study. Additionally, it would also be of interest in future research to conduct this type of training utilizing different resistances and repetition ranges than were utilized in this study. Another consideration for future research would be to make use of the program's provided dietary guide, as it is possible that the inclusion of the P90x® diet plan could further influence the dependent variables measured. A dose-response relationship between physical activity and health and fitness benefits has been observed, demonstrating that increased volume or intensity of physical activity can lead to greater health benefits, up to a point, than lower volumes or intensity of physical activity. Therefore, it could also be of interest to utilize the full 6 days per week training plan, the established P90x® training calendar, and the entirety of the P90x® program to see what additional changes would be observed in dependent variables.

The results of this study demonstrate that P90x® can be an effective tool for the improvement of muscular strength, muscular endurance, and body composition. While it is unclear whether P90x® could significantly address items listed as perceived barriers to exercise, the program could appeal to a wider range of the population than traditional methods of exercise or physical activity. Overall, P90x® can effectively meet and exceed the American College of Sports Medicine's (2014) minimal recommendations for aerobic activity, muscle strengthening activity, stretching, and neuromotor exercises. Further research should be conducted to determine the effectiveness of the P90x® program under different resistances and repetitions, both for the variables measured in this study, as well as aerobic power.

REFERENCES

Alcaraz, P. E., Perez-Gomez, J., Chavarrias, M., & Blazevich, A. J. (2011). Similarity in adaptations to high-resistance circuit vs. traditional strength training in resistance-trained men. *Journal of Strength and Conditioning Research, 25*(9), 2519-2527.

Alcaraz, P. E., Sanchez-Lorente, J., & Blazevich, A. (2008). Physical performance and cardiovascular responses to an acute bout of heavy resistance circuit training versus traditional strength training. *Journal of Strength and Conditioning Research, 22*(3), 667-661.

American College of Sports Medicine. (2014). *ACSM's guidelines for exercise testing and prescription* (9th ed.). Philadelphia: Lippincott, Williams & Wilkins.

American College of Sports Medicine. (2010). *ACSM's resource manual for guidelines for exercise testing and prescription* (6th ed.). Philadelphia: Lippincott, Williams & Wilkins.

Andajani-Sutjahjo, S., Ball, K., Warren, N., Inglis, V., & Crawford, D. (2004). Perceived personal, social and environmental barriers to weight maintenance among young women: A community survey. *International Journal of Behavioral Nutrition and Physical Activity, 1*(15). Retrieved from http://www.ijbnpa.org/content/1/1/15

Arazi, H., & Asad, A. (2012). Multiple sets resistance training: Effects of condensed versus circuit models on muscular strength, endurance and body composition. *Journal of Human Sports and Exercise, 7*(4), 733-740.

Bar-Or, O. (1987). The Wingate anaerobic test: An update on methodology, reliability and validity. *Sports Medicine, 4*(6), 381-394.

Bautista, L., Reininger, B., Gay, J. L., Barroso, C. S., & McCormick, J. B. (2011). Perceived barrier to exercise in Hispanic adults by level of activity. *Journal of Physical Activity and Health, 8,* 916-925.

Bayati, M., Farzad, B., Gharakhanlou, R., & Agha-Alinejad, H. (2011). A practical model of low-volume high-intensity interval training induces performance and metabolic adaptations that resemble 'all-out' sprint interval training. *Journal of Sports Science and Medicine, 10*, 571-576.

Brentano, M. A., Cadore, E. L., Da Silva, E. M., Ambrosini, A. B., Coertjens, M., Petkowicz, R.,… Kruel, L. F. M. (2008). Physiological adaptations to strength and circuit training in postmenopausal women with bone loss. *Journal of Strength and Conditioning Research, 22*(6), 1816-1825.

Brinthaupt, T. M., Kang, M., & Anshel, M. H. (2010). A delivery model for overcoming psycho-behavioral barriers to exercise. *Psychology of Sport and Exercise, 11,* 259-266.

Cerin, E., Leslie, E., Sugiyama, T., & Owen, N. (2010). Perceived barriers to leisure-time physical activity in adults: an ecological perspective. *Journal of Physical Activity and Health, 7,* 451-459.

Chtara, M., Chaouach, A., Levin, G. T., Chaouachi, M., Chamari, K., Amri, M., & Laursen, P. B. (2008). Effect of concurrent endurance and circuit resistance training sequence on muscular strength and power development. *Journal of Strength and Conditioning Research, 22*(4), 1037-1045.

Daskapan, A., Tuzun, E. H., & Eker, L. (2006). Perceived barriers to physical activity in university students. *Journal of Sports Science and Medicine, 5,* 615-620.

Drigny, J., Gayda, M., Sosner, P., Payette, J.-F., Nigam, A., Juneau, M., & Gremeaux, V. (2012). Effects of 4-month high-intensity interval training associated with resistance training program on cognitive performance, cerebral oxygenation, exercise capacity and cardiac output in middle-aged overweight subjects [Abstract]. *Revue d'Épidémiologie et de Santé Publique, 55s,* e314-e315.

Dufield, R., Edge, J., & Bishop, D. (2006). Effects of high-intensity interval training on the VO_2 response during severe exercise. *Journal of Science and Medicine in Sport, 9*, 249-255.

Ebben, W., & Brudzynski, L. (2008). Motivations and barriers to exercise among college students. *Journal of Exercise Physiology*, *11*(5), 1-11. Retrieved from http://www.asep.org/journals/jeponline

Ferreira, F. C., de Medeiros, A. I., Nicioli, C., Nunes, J. E. D., Shiguemoto, G. E., Prestes, J.,… de Andrade Perez, S. E. (2009). Circuit resistance training in sedentary women: body composition and serum cytokine levels. *Applied Physiology, Nutrition, and Metabolism, 35,* 163-171.

Gettman, L. R., Ayres, J. J., Pollock, M. L., & Jackson, A. (1978). The effect of circuit weight training on strength, cardiorespiratory function, and body composition of adult men. *Medicine and Science in Sports, 10*(3), 171-176.

Gettman, L. R., Ward, P., & Hagan, R. D. (1982). A comparison of combined running and weight training with circuit weight training. *Medicine and Science in Sports and Exercise, 14*(3), 229-234.

Gibala, M. J., Little, J. P., MacDonald, M. J., & Hawley, J. A. (2012). Physiological adaptations to low-volume, high-intensity interval training in health and disease. *Journal of Physiology, 590*(5), 1077-1084. Retrieved from http://jp.physoc.org/content/590/5/1077.full.pdf+html?sid=d1e93073-9e3f-435c-9b23-89aa6d0a415e

Gibala, M. J., & McGee, S. (2008). Metabolic adaptations to short-term high-intensity interval training: A little pain for a lot of gain? *Exercise and Sport Sciences Reviews, 36*(2), 58-63.

Godin, G., Desharnais, R., Valois, P., Lepage, L., Jobin, J., & Bradet, R. (1994). Differences in perceived barriers to exercise between high and low intenders: Observations among different populations. *American Journal of Health Promotion, 8*(4), 279-284.

Gotshalk, L. A., Berger, R. A., & Kraemer, W. J. (2004). Cardiovascular responses to a high-volume continuous circuit resistance training protocol. *Journal of Strength and Conditioning Research, 18*(4), 760-764.

Grubbs, L., & Carter, J. (2002). The relationship of perceived benefits and barriers to reported exercise behaviors in college undergraduates. *Family & Community Health, 25*(2), 76-84.

Haltom, R. W., Kraemer, R. R., Sloan, R. A., Hebert, E. P., Frank, K., & Tryniecki, J. L. (1999). Circuit weight training and its effects on excess post-exercise oxygen consumption. *Medicine and Science in Sports and Exercise, 31*(11), 1613.

Harber, M. P., Fry, A. C. Rubin, M. R., Smith, J. C., & Weiss, L. W. (2004). Skeletal muscle and hormonal adaptations to circuit weight training in untrained men. *Scandinavian Journal of Medicine and Science in Sports, 14,* 176-185.

Haskell, W. L., Lee, I.-M., Pate, R. R., Powell, K. E., Blair, S. N., Franklin, B. A., Macera, C. A., . . . Bauman, A. (2007). Physical activity and public health: Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise, 39*(8), 1423-1434.

Heyward, V. H., & Stolarczyk, L. M. (1996). *Applied body composition assessment.* Champaign, IL: Human Kinetics.

Inbar, O., Bar-Or, O., & Skinner, J. S. (1996). *The Wingate anaerobic test.* Champaign, IL: Human Kinetics.

Jackson, A. S., & Pollock, M. L. (1985). Practical assessment of body composition. *Physician and Sports Medicine, 13*(3), 76-90.

Kaikkonen, H., Yrjama, M., Siljander, E., Byman, P., & Laukkanen, R. (2000). The effect of heart rate controlled low resistance circuit weight training and endurance training on maximal aerobic power in sedentary adults. *Scandinavian Journal of Medicine and Science in Sports, 10,* 211-215.

Kessler, H. S., Sisson, S. B., & Short, K. R. (2012). The potential for high-intensity interval training to reduce cardiometabolic disease risk. *Sports Medicine, 42*(6), 489-509.

Laursen, P. B., & Jenkins, D. G. (2002). The scientific basis for high-intensity interval training. *Sports Medicine, 32*(1), 53-73.

Lovell, G. P., Ansari, W. E., & Parker, J. K. (2010). Perceived exercise benefits and barrier of non-exercising female university students in the United Kingdom. *International Journal of Environmental Research and Public Health, 7,* 784-798.

Messier, S. P., & Dill, M. E. (1985). Alterations in strength and maximal oxygen uptake consequent to Nautilus circuit weight training. *Research Quarterly, 56*(4), 345-351.

Mukaimoto, T., & Ohno, M. (2011). Effects of circuit low-intensity resistance exercise with slow movement on oxygen consumption during and after exercise. *Journal of Sports Sciences, 30*(1), 79-90.

National Center for Health Statistics. (2012). *Health, United States, 2011: With special feature on socioeconomic status and health*. Retrieved from http://www.cdc.gov/nchs/data/hus/hus11.pdf

National Strength and Conditioning Association. (2008). *Essentials of strength training and conditioning.* Champaign, IL: Human Kinetics.

Peterson, S. R., Haennel, R. G., Kappagoda, C. T., Belcastro, A. N., Reid, D. C., Wenger, H. A., & Quinney, H. A. (1989). The influence of high-velocity circuit resistance training on VO_2max and cardiac output. *Canadian Journal of Sports Science, 14*(3), 158-163.

Premier Performance, Inc. (1996). Health history questionnaire. Decatur, Georgia.

Rowan, A., Kueffner, T. E., & Stavrianeas, S. (2012). Short duration high-intensity interval training improves aerobic conditioning of female college soccer players. *International Journal of Exercise Science, 5*(3), 232-238.

Siahkouhian, M., Khodadadi, D., & Shahmoradi, K. (2013). Effects of high-intensity interval training on aerobic and anaerobic indices: Comparison of physically active and inactive men. *Science & Sports, 28*(5), e119- e125. Retrieved from http://dx.doi.org/10.1016/j.scispo.2012.11.006

Sperlich, B., Zinner, C., Heilemann, I., Kjendlie, P-L, Holmberg, H-C, & Mester, J. (2010). High-intensity interval training improves VO_{2peak}, maximal lactate accumulation, time trial and competition performance in 9-11-year old swimmers. *European Journal of Applied Physiology, 110*(5), 1029-1036.

Terada, T., Friesen, A., Chahal, B. S., Bell, G. J., McCargar, L. J., & Boulé, N. G. (2012). Feasibility and preliminary efficacy of high intensity interval training in type 2 diabetes. *Diabetes Research and Clinical Practice, 99*(2), 120-129. Retrieved from http://dx.doi.org/10.1016/j.diabres.2012.10.019

Tong, T. K., Chung, P. K., Leung, R. W., Nie, J., Lin, H., & Zheng, J. (2011). Effect of non-Wingate-based high-intensity interval training on cardiorespiratory fitness and aerobic-based exercise capacity in sedentary subjects: A preliminary study. *Journal of Exercise Science & Fitness, 9*(2), 75-81.

Wilmore, J. H., Parr, R. B., Ward, P., Vodak, P. A., Barstow, T. J., Pipes, T. V., … Leslie, P. (1978). Energy cost of circuit weight training. *Medicine and Science in Sports, 10*(2), 75-78.

Wisloff, U., Ellingsen, O., & Kemi, O. J. (2009). High-intensity interval training to maximize cardiac benefits of exercise training? *Exercise and Sport Sciences Reviews, 37*(3), 139-146.

Woldt, J. (2011). Determining the energy cost and exercise intensity of four of the P90x workouts (Unpublished master's thesis). University of Wisconsin, La Cross. Retrieved from http://minds.wisconsin.edu/handle/1793/53465

APPENDICES

APPENDIX A

Middle Tennessee State University Institutional Review Board Form

February 17, 2014
Casey Clark
Protocol Title: **THE EFFECT OF 4 WEEKS OF P90X® TRAINING ON MUSCULAR STRENGTH AND ENDURANCE, ANAEROBIC POWER, AND BODY COMPOSITION**
Protocol Number: 14-145
Dear Investigator(s),

The MTSU Institutional Review Board or its representative has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study meets the criteria for approval under 45 CFR 46.110 and 21 CFR 56.110, and you have satisfactorily addressed all of the points brought up during the review.

Approval is granted for one (1) year from the date of this letter for 100 participants. Please use the version of the consent form with the compliance office stamp on it that will be emailed to you shortly.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918. Any change to the protocol must be submitted to the IRB before implementing this change.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished collecting and analyzing data. Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date. Please allow time for review and requested revisions. Failure to submit a Progress Report and request for continuation will automatically result in cancellation of your research study. Therefore, you will NOT be able to use any data and/or collect any data.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to complete training (there is no need to include training certificates in your correspondence with the IRB). If you add researchers to an approved project, please forward an updated list of researchers to the Office of Compliance (compliance@mtsu.edu) before they begin to work on the project.

All paperwork, including consent forms, needs to be given to the faculty advisor for storage. All research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion and then destroyed in a manner that maintains confidentiality and anonymity.

Sincerely,
Paul S. Foster, Ph.D.
Associate Professor
Psychology Department

APPENDIX B

Informed Consent Form

Principal Investigator: Casey Clark
Study Title: Assessment of 4 weeks of P90x® training on muscular strength and endurance, anaerobic power, and body composition
Institution: Middle Tennessee State University
Name of participant:
____Age:___________

The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form.

Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. **Purpose of the study:**
   You are being asked to participate in a research study because you are physically active and likely more tolerant of the high intensity exercise that will be utilized in this study. The purpose of this study is to evaluate the effect of 4 weeks of P90x® exercise training on measures of upper and lower body muscular strength and endurance, anaerobic power, and body composition.
2. **Description of procedures to be followed and approximate duration of the study:**
   You will be tested on upper body muscular strength with a 1-rep max (1RM) bench press and lower body muscular strength with a 1RM half-squat; upper body and lower body muscular endurance through maximal repetitions at 50% of your 1RM on the same exercises used for strength testing; anaerobic power, through a Wingate Anaerobic Test; and body composition, via a 7-site skinfold measurement. Training will consist of group sessions, involving a maximum of 15 participants per group, for 6 days per week for a total duration of 4 weeks. Following the training intervention, you will again be tested on upper and lower body muscular strength and endurance, anaerobic power, and body composition. Including familiarization, testing procedures, and intervention, total duration of participant involvement in the study will be approximately 7 weeks.
3. **Expected costs:**

There are no costs associated with participation.

4. **Description of the discomforts, inconveniences, and/or risks that can be reasonably expected as a result of participation in this study:**
You can expect an elevated heart rate, temporary muscle fatigue, and/or shortness of breath during training sessions. Physical fatigue and muscle soreness can be expected following the beginning of the training intervention. With any form of exercise, there is risk of muscle strains and physical injury.

5. **Compensation in case of study-related injury:**
MTSU will not provide compensation in the case of study-related injury.

6. **Anticipated benefits from this study:**
a) The potential benefits to science and humankind that may result from this study are increased understanding of the benefits of extreme home conditioning programs on factors of health-related fitness and the benefit of high-intensity interval resistance training on muscular strength and endurance, anaerobic power, and body composition over a 4-week period.
b) The potential benefits to you from this study are: increased muscular strength and endurance; increased anaerobic power; improved body composition; greater understanding of muscular strength and endurance measures and technique; experience of new and alternative form of exercise than traditional methods; increased motivation for performance due to group exercise environment.

7. **Alternative treatments available:**
There are no alternative treatments being offered.

8. **Compensation for participation:**
There will be no compensation for participating.

9. **Circumstances under which the Principal Investigator may withdraw you from study participation:**
You may be withdrawn from study if you fail to attend initial testing sessions for baseline values. Your data may be excluded from analysis and inclusion in final reports of the study if you miss more than 1 day of training per week.

10. **What happens if you choose to withdraw from study participation?**
There are no consequences for choosing to withdraw from study participation. You can choose to withdraw at any time if unwilling or unable to continue with testing or the exercise intervention. Any data collected will not be used in analysis.

11. **Contact Information.** If you should have any questions about this research study or possible injury, please feel free to contact Casey Clark at 931-636-2329 or my Faculty Advisor, Jenn Caputo, at 615-898-5547 or Richard Farley at 615-818-5298.

12. **Confidentiality**. All efforts, within reason, will be made to keep the personal information in your research record private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State

University Institutional Review Board, Federal Government Office for Human Research Protections, if you or someone else is in danger or if we are required to do so by law.

13. STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY

I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I freely and voluntarily choose to participate in this study.

_______________ ____

Date Signature of patient/volunteer

Consent obtained by:

________________ ____

Date Signature

____

Printed Name and Title