THE INFLUENCE OF A CROSSFIT EXERCISE INTERVENTION ON GLUCOSE CONTROL IN OVERWEIGHT AND OBESE ADULTS

by

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Abstract

Background: The American College of Sports Medicine physical activity guidelines call for 150 minutes of moderate or 75 minutes of vigorous aerobic exercise plus two days of resistance training (A-RT) per week for health benefits. Yet, most adults do not achieve the recommended amount of physical activity per week frequently citing lack of time as a barrier. High-intensity exercise protocols have improved glucose control, insulin sensitivity, fitness, and body composition, in less total time than lower intensity protocols, but have been studied as singular modes of exercise. CrossFit (CF) temporally combines A-RT together utilizing constantly varied multi-joint, full range-of-motion movements in substantially less training time than lower-intensity protocols. The aim of this study was to compare the effects of CF versus A-RT on glucose control in overweight/obese, physically inactive individuals.

Methods**:** Eighteen overweight/obese (BMI 30.3 ± 2.8) adults (28.5 ± 5.9 years) were randomized to one of two groups: CF (3 days/week for 60 minute sessions) or A-RT (3 days/week of aerobic exercise for 50 minutes, plus ~20 minutes resistance exercise on 2 of those days) over 8-weeks. Fasting plasma glucose and 1-hour oral glucose tolerance tests were taken at baseline and post-training along with Eurofit fitness measures, VO_2 peak, and body composition via dual energy X-ray absorptiometry.

Results**:** Glucose control and body composition did not change significantly within or between groups. Both groups significantly improved muscular endurance (pushups completed on knees, CF+39.5%, $p < 0.05$; A-RT+24.4%, $p = 0.01$). The CF group improved on number of situps (CF+6.8%, $p = 0.01$) and VO_2 peak (CF+9.1%, $p < 0.05$). Time spent exercising was significantly different between groups with the CF group averaging 38.7 ± 15.6 minutes per week and 13.1 ± 0.9 minutes per workout, and the A-RT group averaging 190.0 ± 10.7 minutes per week and 63.3 ± 3.6 minutes per workout.

Conclusion**:** Eight weeks of A-RT or CF did not produce significant changes in glucose control or body composition in overweight/obese adults. However, despite exercising significantly less time per week CF training demonstrated greater improvements in fitness measures than A-RT.

Table of Contents

List of Tables

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Dedication

This thesis is dedicated to my family, my mother, father, and sister. With your help, encouragement, and support, this entire study was possible.

Chapter 1 - Introduction

The most common health disorder in America is obesity; obesity is associated with increased mortality and morbidity for cardiovascular disease (CVD), the number one killer of Americans today (23). Obesity has become a major health care concern and public health challenge in the United States (US). Over 2/3 of US adults are either overweight or obese (23). Two major health issues that are common with obese individuals include insulin resistance and type 2 diabetes mellitus (T2DM; 34).

Prevention and treatment of insulin resistance, a characteristic shown in those with T2DM, is a high priority in health care today. Individuals with insulin resistance and T2DM are characterized by impaired insulin action on whole-body glucose uptake, which is due in part to impaired insulin-stimulated glucose uptake in skeletal muscle (33). Insulin resistance can occur as a result of a decreased insulin responsiveness or sensitivity. Insulin sensitivity is characterized by the body's response to insulin and ability to uptake glucose.

Preventing and managing diabetes is important to prevent any further complications such as dyslipidemia, hypertension, cardiovascular disease, stroke, blindness, kidney disease, and neurodegeneration if interventions are not made (34). Exercise has been prescribed as a popular and effective intervention in the prevention and management of diabetes. According to the American College of Sports Medicine (ACSM) and the American Diabetes Association (ADA), physical activity for those with prediabetes or diabetes should total 150 minutes a week of moderate or 75 total minutes of vigorous intensity aerobic activity throughout the week, with no more than two consecutive days between bouts of aerobic activity (1, 31).

Exercise training (both aerobic and resistance) has been shown to improve insulin sensitivity in a multitude of overweight and obese populations (5, 9, 14, 18). One goal of exercise is to improve the action of insulin in those who are insulin resistant. Exercise stimulates glucose transport activity through an insulin-independent mechanism, therefore lowering blood glucose levels that are normally higher in those with diabetes and insulin resistance (10). Aerobic exercise can improve insulin sensitivity, resistance training can improve insulin resistance, and a combination of both can improve blood glucose control (1).

Despite the evidence on health benefits of regular physical activity, the percentage of US adults meeting recommended physical activity guidelines is low (7). Only about 22% of adults report engaging in regular physical activity. Most adults do not achieve the recommended amount of moderate to vigorous physical activity in minutes per week, and some 25% of adults report that they never engage in any physical activity (24). The most frequent barrier to exercise reported by both sedentary and active individuals is time constraints, followed by accessibility (24). An ideal program would target these key barriers to exercise participation by providing a time-efficient work out and accessible facilities and programs (24).

A growing body of evidence indicates that individuals who participate in higher intensity exercise or High-Intensity Functional Training (HIFT; functional training that mimics movements seen or experienced in everyday life) achieve greater improvements on fitness measures, fitness scores, and aerobic capacity when compared to a lower or more moderate-intensity, longer duration program (12). High-intensity training protocols address time as a barrier by providing fitness benefits while taking less time to complete than moderate intensity programs (7), yet have typically been studied as singular modality training protocols (13, 26).

One unique type of HIFT exercise program that addresses time as a barrier is CrossFit (CF; 35). CF workouts are designed to produce gains in work capacity and strength in the shortest possible amount of time due to constantly varied workouts that stress multiple energy systems at a relatively high intensity with little rest (19). Although anecdotal stories abound (19), documentation of studies citing benefits of CF, including its ability to improve health and well-being and prevent or alleviate the development of chronic diseases, especially T2DM and insulin resistance, are non-existent. The CF method may provide substantial and significant improvements in health and fitness by combining the A-RT modalities prescribed by the ACSM and ADA done at relatively high intensity by combining weightlifting, monostructural, and gymnastics movements to elicit an improvement in glucose control while taking less time to accomplish per session compared to lower intensity protocols.

Purpose

The purpose of this study was to examine the differences in glucose control, fitness (Eurofit and peak aerobic capacity), and body composition (body fat percentage, fat mass, and lean body mass) between a standard aerobic and resistance exercise training program (A-RT) and a shorter-duration, high-intensity CF training program in overweight and obese physically inactive adults.

Testable Hypotheses

Hypothesis 1

It was hypothesized that both the A-RT and CF exercise groups would improve glucose control, with the CF group improving significantly more than the A-RT group.

Hypothesis 2

It was hypothesized that both the A-RT and CF exercise groups would improve fitness, with the CF group improving significantly more than the A-RT group.

Hypothesis 3

It was hypothesized that both the A-RT and CF exercise groups would demonstrate decreases in body fat percentage and fat mass and increases in lean body mass, with the CF group improving significantly more than the A-RT group.

Chapter 2 - Literature Review

This first part of this literature review will highlight information gathered from studies that describe the changes and adaptations to glucose control and insulin sensitivity that the body undergoes during exercise (aerobic, resistance, and combined aerobic and resistance) in those more at risk for developing T2DM (overweight and obese populations), and how these different types of exercise modalities influence insulin resistance and insulin sensitivity in these at-risk populations. Exercise intensity will be the focus of the second part of this literature review. The effects of exercise intensity on insulin resistance, effects of high-intensity exercise on fitness outcomes and fat body composition, and how CF can be utilized as an appropriate exercise intervention will be discussed. It is therefore the intent of this literature review to discuss how a CF exercise intervention can be utilized to improve glucose control, fitness, and body composition.

Exercise, Glucose Control, and Insulin Resistance in Overweight/Obese Individuals

Exercise plays an important role in improving insulin sensitivity and reversing insulin resistance. The ACSM and ADA have prescribed aerobic exercise as a means of improving symptoms and reversing the effects of T2DM (1). Aerobic exercise stimulates blood glucose utilization during and after exercise and exercise induces a substrate shift between free fatty acids, glycogen stores, and circulating glucose; exact balance varies with duration and intensity of physical activity (10). With repeated bouts of aerobic exercise, the recruited muscles undergo adaptations that improve synthesis of key components (intracellular transporters and enzymes) needed for glucose uptake and metabolism. Aerobic exercise at low to moderate intensities results in decreased insulin secretion during exercise and a decline in blood glucose and insulin levels. Glucose uptake is stimulated by previously activated muscle fibers when insulin sensitivity has been enhanced by exercise (10).

Aerobic Exercise

Varying durations of aerobic exercise protocols have improved insulin sensitivity in overweight and obese individuals with and without changes in body weight (9, 14, 18).

Improvements in insulin sensitivity were found in obese elderly individuals who participated in 12 weeks of aerobic exercise (5 days/wk, 60 min/day, treadmill/cycle-ergometry at ~70% maximal aerobic capacity (VO_2 max); 18). Participants' body weight was reduced by 3% from the exercise protocol alone. A 12-week aerobic exercise study (4x30 min/wk, ≥ 70% VO_2 max) conducted with sedentary lean and obese Hispanic adolescents resulted in both groups increasing insulin sensitivity without weight loss (14).

Aerobic exercise facilitates the clearance of glucose from the circulation and metabolism of glucose in exercised skeletal muscle. Specifically, blood glucose levels are lowered during and immediately after exercise by glucose oxidation and improved insulin sensitivity. It also enhances the ability of insulin to activate glucose transport into exercised muscles facilitating re-synthesis of glycogen, an effect lasting for hours following exercise cessation (10).

Resistance Training

In addition to the benefits of aerobic exercise training, resistance training also improves insulin sensitivity and is recommended by the ACSM and ADA for added benefits to glucose control in those with T2DM (1). Resistance training increases muscle mass, which allows for a larger reservoir for glucose disposal. The contraction of skeletal muscle stimulates glucose transport and metabolism through a pathway independent of insulin therefore lowering plasma glucose levels (10). Studies in adults have shown increased strength, muscle mass, and insulin sensitivity in response to resistance exercise programs (3, 6, 22). For example, adults with impaired glucose tolerance (IGT) at risk of T2DM improved insulin sensitivity following 4 months of endurance resistance training (ERT) or maximal resistance training (MRT; 11). Additionally, MRT led to a greater increase in glucose uptake in skeletal muscle and ERT led to greater insulin sensitivity (11).

Improvements in insulin sensitivity, increases in lean body mass, and decreases in fat mass have been seen after 6, 12, and 16 weeks of resistance training (3, 5, 22). A 6-week whole body resistance exercise program (3 days/wk, 3x8-12 at 80% 3-RM) was examined for effects on glucose control in obese women with T2DM and age matched obese controls. Lean body mass increased significantly in the control group while fat mass decreased significantly in the diabetic group. The diabetic group significantly improved integrated glucose concentration after the bouts of exercise resulting in improved insulin sensitivity during the postexercise period (5).

Similar improvements in body composition and insulin sensitivity were seen with 12 weeks of resistance training (45-60 min weight training on Nautilus equipment utilizing large muscle groups) in normal weight young (23 ± 1 year) and elderly adults (63 ± 1 year) with non-insulin dependent diabetes mellitus (NIDDM). Both groups increased weight and lean body mass and decreased body fat and insulin concentration (3). A longer 16-week resistance training study resulted in increases in lean body mass and decrease in body fat percentage in overweight adolescent Latino males (2 days/wk for 60 min; 22). The resistance training group also significantly increased mean insulin sensitivity compared with baseline, while 60% of control participants experienced less insulin sensitivity (22).

In summary, improvements to glucose control have been experienced with resistance training. Resistance training offers an additional outlet for those not interested in participating in aerobic training alone. There are also direct effects on skeletal muscle that increase glucose transport activity as well as the loss of visceral adipose tissue which has been linked to the development of insulin resistance (10).

Combined Aerobic and Resistance Training

A combination of aerobic and resistance training may be a more effective intervention for blood glucose management than aerobic training or resistance training alone. The ACSM and ADA deem the best type of exercise prescription to be one that combines both aerobic exercise and resistance training (1), with improvements in glucose control resulting from protocols combining aerobic exercise and resistance training (A-RT; 17, 27). For example, 8 weeks of A-RT (3 one-hour sessions/wk) improved glucose control and decreased body fat percentage in 16 overweight subjects with T2DM (17). Sixteen weeks of A-RT in nine overweight, physically inactive women with T2DM led to significant improvements of glucose control and insulin action, with minimal changes to body mass (27). Exercise protocols combining A-RT exhibit the benefits of both aerobic exercise (increased cardiovascular fitness) and resistance training (increased muscle mass and strength; 17), as well as improvements to insulin sensitivity (27).

Exercise, Insulin Resistance, and Intensity

Intensity and duration of physical activity influence substrate use during exercise (10). With increasing exercise intensity there is a greater reliance on carbohydrate as a fuel source. High intensity exercise leads to rapid depletion of glycogen stores in contracting muscle fibers.

The hyperglycemic and hyperinsulinemic setting that occurs immediately after high intensity exercise is crucial in promoting rapid rates of glycogen replenishment in depleted muscle fibers and improving insulin sensitivity (10).

Six months of A-RT group-based exercise training in women with T2DM increased insulin sensitivity in the group that performed at a higher intensity (21). The change in insulin sensitivity was significantly correlated with training intensity and volume, but not duration. Thus, higher exercise intensity resulted in significant improvements over lower intensity exercise, especially for insulin sensitivity in T2DM women (21). Exercise intensity is a better predictor of improvements in blood glucose control than exercise volume. Exercise at higher intensity results in decreased insulin secretion; reductions in blood glucose are related to intensity and duration of exercise, and more intense physical activity enhances insulin action for a longer period of time (1).

High-Intensity Training, Fat Loss, and Fitness

High-intensity interval training (HIIT) protocols are completed in a significantly shorter amount of time and volume than traditional or standard low to moderate-intensity exercise protocols. HIIT protocols address the commonly cited barrier to engaging in regular physical activity, perceived lack of time (7). HIIT protocols require considerably less total energy expenditure but are done at a higher and more vigorous intensity with the hopes of eliciting greater improvements to body composition, and fitness goals long after exercise training has ceased (7).

High-intensity exercise significantly improved postexercise fat metabolism, even in shorter exercise durations (30). A comparison of 12-15 minutes of cycling at high-intensity (85% VO_2 max) versus 30 minutes of low-intensity (50% VO_2 max) resulted in respiratory exchange ratio (RER) declines below basal values for almost the entire 90-minute postexercise period for the high-intensity group, while no change in RER from basal was exhibited in the low-intensity group (30). Mean fat oxidation and total fat oxidation increased with time to above the basal rate after high- but not low-intensity exercise.

High-intensity exercise is also correlated with reductions in body fat. Fifteen weeks of high-intensity intermittent exercise (HIIE) resulted in significant reductions in total and abdominal fat and significant increases in trunk lean body mass when compared to steady state exercise (SSE) and control counterparts (28). The HIIE protocol took significantly less time to complete.

Improvements in cardiorespiratory fitness have also been studied using high-intensity training protocols (13, 26). The effects of a 6-week intervention of moderate intensity and HIIT using cycle ergometers were examined in 14 young male students (23 ± 1 year; 26). Maximal aerobic capacity (VO_2 max+7 mL/kg/min) increased significantly after both HIIT and endurance training (VO_2 max+5 mL/kg/min; 26). Similar improvements in aerobic capacity were shown after 8 weeks of HIT (13). As well, significant improvements to VO_2 max were found for two high-intensity groups (+5.5% and +7.2%) as compared to two lower intensity, longer duration protocols. Thus high-intensity aerobic training was significantly more effective than moderate and low-intensity training in improving VO_2 max (13, 26). HIFT circuit training (15 sessions over 8 weeks, 15 exercises done for 60-90 seconds for 45 minutes; n = 34, aged 27.29 ± 5.68 years, 28 males) was compared to traditional Army physical training (15 sessions over 8 weeks, 60 minutes; n = 33, aged 27.88 ± 5.38 years, 28 males) for active duty military personnel (12). The circuit training consisted of multiple functional exercises using various planes and movements done at different speeds including weight training and body weight exercises. The HIFT group significantly increased fitness levels (muscular and cardiorespiratory endurance, strength, and flexibility), as compared to the Army physical training group (12).

In summary, HIIT, HIIE, and HIFT have elicited improvements in fitness and aerobic capacity when compared to lower intensity more traditional exercise training regimens (12, 13, 26). Greater improvements in fat oxidation and decreases in body fat resulted from high-intensity training protocols that took less time to complete than lower-intensity longer duration protocols (28, 30). However, most high-intensity protocols utilize singular exercise modalities rather than the A-RT prescription set forth by the ACSM and ADA. A high-intensity protocol combining A-RT elements might result in greater improvements in glucose control, body composition, and fitness than a lower-intensity longer duration A-RT exercise protocol.

CrossFit

CrossFit is a unique type of HIFT that combines functional movements and is designed to be constantly varied and have a timed or scored component to each workout. These timed and scored components dictate how much work is accomplished during a certain period of time.

Two quazi-experimental studies with non-randomized participants examined user-submitted data for specific CF workouts over four time points (19). Individuals who participated in regular CF training improved muscular endurance and strength over time. Similar improvements to fitness were experienced in a military population when CF training was compared to a standard Army fitness program in a quazi-experimental non-randomized group experiment (8). After 12 weeks of training the CF groups experienced equal or greater cardiovascular improvements while performing less than half the running, and results suggested that the CF groups matched or out performed the standard groups (8). CF may also prove to be a effective training method than less intense protocols for improving glucose control, fitness, and body composition in overweight and obese individuals due to combining aspects of aerobic and resistance training together to be done at relativity high intensities in a short amount of time.

Summary

This review has shown that when completed as singular modalities, aerobic exercise improved insulin sensitivity in overweight and obese individuals, resistance training improved insulin sensitivity in insulin resistant populations and increased lean body mass, and both combined helped increase aerobic capacity, fat oxidation, and lean body mass, all of which improved insulin sensitivity. Exercise intensity also played a role, with higher intensity exercise providing more benefits (e.g., improvements in fitness, decreases in fat mass, and improvements to body composition) than exercise at lower intensities. A combined A-RT exercise program done at a high-intensity might be the best prescription for improving insulin sensitivity in those with T2DM.

Insulin resistance and T2DM affect populations of all ages, body types, and races. Prevention is key; finding exercise interventions that help prevent insulin resistance and IGT from developing into T2DM is crucial in those more at risk for developing T2DM (overweight and obese populations). A training study utilizing methodology that temporally combines both aerobic exercise and resistance training together has not previously been conducted in these more at-risk populations. The effect of a CF type exercise program on health and fitness outcomes is currently unknown, especially when examining at its effect on glucose control in overweight and obese adults.

Chapter 3 - Methods

Research Design and Methods

This 8-week randomized controlled pilot trial used a pretest, posttest comparison group design. This study was approved by the institutional review board (IRB) at Kansas State University, and all testing and intervention procedures were conducted on campus.

Participants

Inclusion criteria included non-smoking males or females between ages 18-40, with a body mass index (BMI) of 25 - < 40, who were physically inactive (i.e., not participating in any structured exercise programs for the past 2 months and not exceeding 30 total minutes of physical activity per week), who were not pregnant or planning on getting pregnant during the intervention, who were not taking any blood glucose altering medications, who had no diagnosis of heart disease, or type 1 or T2DM, and total cholesterol < 200 mg/dL. Participants who had been diagnosed with pre-diabetes were eligible to participate. Subjects were not discriminated by age, gender, or ethnicity and similar subjects were randomized to each experimental group through random stratified assignment (age, body mass index ranges). The A-RT Group consisted of 11 participants: 3 males and 8 females, 28.0 ± 5.7 years. The CF Group consisted of 12 participants, 7 males and 5 females, 28.3 ± 7.1 years.

Recruitment

Flyers, word of mouth, radio public service announcements, on-campus recruitment, K-State Today email blast, posters at local businesses, and referrals were used to recruit participants. Interested participants completed a screening form to determine eligibility. The screening form queried height, weight, and age, physical activity level (if the potential participant was getting more or less than 30 minutes of total physical activity per week), and general health questions (any diagnosed cases of heart disease, diabetes, smoking, pregnancy, et cetera). Individuals meeting the eligibility criteria were then given an informed consent form, a medical history questionnaire, and a demographic information sheet. Due to the number of interested individuals, eligible participants were required to complete and submit the documents by a specified due date. Those that did qualified to participate in the exercise intervention study.

Measures

Pretests

All pretests were completed at baseline, 1 week prior to commencing the exercise intervention.

Glucose Control

Fasting plasma glucose (FPG) levels were taken in the morning after an overnight fast of at least eight hours. Immediately following the FPG test, an oral glucose tolerance test (OGTT) was administered. Participants were given a 75g oral dextrose solution to consume. Time 0 was documented for each participant at the time of ingestion of the entire solution. Finger sticks were then taken at 30 minutes, 45 minutes, and 60 minutes from time 0.

Peak Aerobic Capacity (VO_2 peak)

VO_2 peak was assessed using an incline treadmill test (i.e., Modified Balke Protocol); gas exchange and metabolic measurements were taken using Parvomedics TruOne 2400 (36). Prior to each session gas and flowmeter calibration was conducted. Participants wore a heart rate monitor for the entire duration of the test. Each participant was given a 60 second warmup period walking on the treadmill at 3 miles per hour. The treadmill speed was then increased to 4.5mph for women and 5mph for men, and kept constant, while increasing the incline 1% for each successive minute. Heart rate (bpm), relative VO_2 ml/kg/min, and respiratory exchange ratio (RER) were recorded for each minute of exercise. The test stopped as soon as the participant placed their hands on the treadmill handle signaling the end of the test. The highest VO_2, heart rate, and RER during the session were recorded as peak values.

Fitness

Fitness was assessed by administering a battery of Eurofit measures (sit and reach, standing broad jump, vertical jump, pushups and situps; 29) along with additional fitness tests (40m dash and stork balance test; 15). Participants began by running a 40m dash to assess speed. Power was measured by two attempts at both vertical jump and standing broad jump (29). A reach height was determined and participants were given two attempts to obtain a jump height. Jump height of the highest jump was then subtracted from reach height to determine vertical jump. Muscular strength and endurance were measured using a 30 second test for pushups and situps (29). All participants were given the option to do pushups on their knees, and all participants were asked to touch his or her chest to a mat for a proper rep. Situps were completed with an individual standing on the participant's toes to act as an anchor. Participants were asked to complete a full situp by bringing their upper torso completely off the mat to their knees and were asked to touch the shins of the individual acting as an anchor. Flexibility was measured using the sit and reach test (29). Balance was measured using the stork balance test (15).

Body Composition and Anthropometry

Prior to the FPG and OGTT tests, height, weight, waist circumference, and resting heart rate were recorded. A BMI < 18.5 was defined as underweight, 18.5-24.9 was normal weight, 25-29.9 was overweight, and ≥ 30 was obese (25). Waist circumference was measured by placing a measuring tape 1" above the umbilicus around the waist of the participant. Body composition was measured via dual energy X-ray absorptiometry (DEXA) scan (16).

Resting Heart Rate

Resting heart rate was taken to calculate heart rate reserve (HRR) and used for aerobic training guidelines in the A-RT group. Resting heart rate was recorded using POLAR heart rate monitors and straps and used to calculate HRR (Max HR - Resting HR = HRR).

Participant Randomization and Group Selection

All participants were coded by age and BMI and were assigned a number based upon each characteristic. Median and mean were calculated for age and BMI and cut points were assigned from those numbers. A random number generator was used to assign participants to groups resulting in 12 participants (7 males, 5 females) in the CF group and 11 in the A-RT group (8 females, 3 males). All participants were asked to continue their normal dietary intake and to refrain from doing any extra physical activity outside of the study.

Exercise Intervention

Both exercise groups, A-RT and CF, could choose to attend either a morning or evening session on Mondays, Wednesdays, and Fridays.

A-RT Exercise Group

Participants began each training session by checking in and receiving a heart rate strap and heart rate monitor as well as an individualized workout plan. Aerobic (50 minutes on a C2 rower, Quinton or Precor treadmill, Precor or Vision Fitness elliptical, or Vision Fitness stationary bike) and resistance training activities (20 minutes using CYBEX machines) were performed on Mondays and Wednesdays and only aerobic activities (50 minutes) were performed on Fridays. Participants were allowed to switch between machines as long as a minimum of 10 minutes were performed on each aerobic machine. Activities were based upon the ADA and ACSM guidelines to meet the 150 minutes of moderate-intensity aerobic physical activity plus at least two days of muscle strengthening exercises per week. Heart rate monitors were used to ensure participants stayed within a specific heart rate range based on percentages of HRR. Table 3.1 depicts the training protocol used for HRR ranges. Table 3.2 shows resistance training exercises completed and Table 3.3 shows the breakdown of sets, reps, and intensity.

Aerobic Training Protocol

Table 3.1 Aerobic Training Protocol for A-RT Group

Weeks 1-4	40-50% HRR
Weeks 5-8	50-60% HRR

Resistance Training Protocol

Table 3.2 Resistance Training Protocol for A-RT Group

Monday	Wednesday
Seated Bicep Curl (Biceps)	Tricep Pulldown (Triceps)
Military Press (Deltoids)	Bench Press (Pectoralis)
Seated Lat Pulldown (Latissimus Dorsi)	Reverse Leg Curl (Hamstrings)
Seated Leg Extension (Quadriceps)	Seated Leg Press (Gluteus Maximus)
Crunches (Abdominals)*	Crunches (Abdominals)*

*Crunches done on a gymnastics mat

Participants were asked to find the maximum amount of weight they were able to lift for each of the exercises done on a machine in week 1. A light weight was lifted for 10 repetitions and then increased while decreasing the rep scheme until achieving a one-repetition maximum (1-RM). Percentages of weight for weekly resistance training sessions were calculated using the determined 1-RM. One minute of rest was observed between each set of a lift and between each exercise completed.

Table 3.3 Resistance Training Protocol By Week

Week 2 and 3	50% 1RM	3 sets of 15 reps
Week 4 and 5	60% 1RM	3 sets of 12 reps
Week 6 and 7	70% 1RM	3 sets of 10 reps
Week 8	75% 1RM	3 sets of 8 reps
Crunches were 3x15 each week		

An American Council on Exercise (ACE) certified personal trainer supervised A-RT participants during the resistance training sessions in order to ensure participants were completing the entire protocol, to answer questions about movements, and to demonstrate proper technique and form.

CF Exercise Group

Participants completed a total of 24 sessions that were preprogrammed and led by a certified CF Level 2 instructor, which lasted up to 60 minutes in duration. The first two class periods were structured as an introduction to common movements used in CF (e.g., squats, deadlift, press, jerks, barbell, dumbbell, and medicine ball cleans, pullups, kettlebell swings, among others). No scheduled workouts were given on days 1 and 2. Beginning on day 3 each CF class consisted of 10-15 minutes of stretching and warmup, 10-20 minutes of instruction and practicing techniques and movements, and 5-30 minutes for the workout of the day (WOD), performed at vigorous intensity, relative to each person's ability and fitness level. All weights and movements were individually prescribed and recorded for each CF participant. A list of all workouts completed by the CF group is displayed in Appendix B. Depending on the WOD structure, the times to complete the WOD, rounds and repetitions completed on the WOD, weights used, and any modifications needed from the programmed workout were also recorded for each participant. Average times for each WOD, total WOD time per week, and total average WOD time per week were calculated for the CF group as a whole.

Makeup Sessions

Makeup sessions were provided for participants who gave notification prior to an absence. No makeup sessions were given for missing sessions without prior notification, or if a participant missed a scheduled makeup session.

Posttests

All participants completed each measure (FPG, OGTT, body composition, fitness- except resting heart rate-, and peak aerobic capacity) during the week following the completion of the exercise intervention. All tests were conducted and recorded using identical procedures as the pretest measures. Of note, one participant in the CF group did not complete the posttest 40m dash due to a lower body posterior injury sustained outside of the intervention. The DEXA measurements were delayed for 2 weeks due to a computer malfunction. Participants were neither asked to refrain from participating in any physical activity during the delay with the DEXA, nor was their activity monitored.

Participants were also asked to complete a second portion of the demographic information sheet as well as an exit screening questionnaire to assess their expectations and satisfaction with the 8-week exercise intervention, if they engaged in any extra physical activity outside of the scheduled workout sessions, daily health habits, motivation for exercise, self-confidence and self-perceptions, and future plans for continuing to exercise. After each of the posttest measures were completed, individual results were presented to each participant by email along with brief explanations of their results. After the conclusion of the intervention, participants were provided with an incentive of a free 1-month membership to the Adult Fitness Program or 1 free month of CF classes at Kansas State University.

Statistical Analyses

All data were entered into SPSS 18 for statistical analyses and comparisons. Descriptive statistics including means, standard deviations and percentages were computed for all participant demographics by group. The equation used to calculate glucose area under the curve (AUC) was as follows:

$$[(\text{Time } 45 - \text{Time } 30) * \tfrac{1}{2} (\text{OGTT } 30 + \text{OGTT } 45)] + [(\text{Time } 60 - \text{Time } 45) * \tfrac{1}{2} (\text{OGTT } 60 + \text{OGTT } 45)]$$

Hypotheses Tests

Hypotheses tests were conducted only for the participants that completed the entire intervention (n = 18). For all analyses, the level of significance was set at $p < 0.05$. Independent samples t-tests were conducted on each measure to determine if there were any significant differences between groups at baseline. Data are presented as mean (SD) unless otherwise noted.

Hypothesis 1

For hypothesis 1, paired t-tests were first conducted to see if there were any significant within-group changes in glucose AUC from pretest to posttest. Second, a univariate analysis of covariance (ANCOVA) was conducted with the baseline testing value as the covariate and group as the constant to evaluate between-group differences for changes in glucose AUC from pretest to posttest.

Hypothesis 2

For hypothesis 2, paired t-tests were conducted to see if there were any significant changes in VO_2 peak and each fitness measure from pretest to posttest within each group. Then, a univariate ANCOVA was conducted with the baseline testing values as the covariate and group as the constant to see if there were any significant differences for changes in VO_2 peak and each fitness measure from pretest to posttest between groups.

Hypothesis 3

For hypothesis 3, paired t-tests were conducted to see if there were any significant changes in body composition from pretest to posttest within groups. Finally, a univariate ANCOVA was conducted with the baseline testing values as the covariate and group as the constant to see if there were any significant differences for changes in body composition from pretest to posttest between groups.

Chapter 4 - Results

Completed Sessions, Attrition Rates, and Enjoyment of Exercise

Eighteen participants completed the intervention (9 in the A-RT group, 7 females 2 males; and 9 in the CF group, 5 females 4 males) by attending or making up at least 90% of the 24 scheduled exercise sessions. Attrition rate in the A-RT group was 18.2% (*n* = 2, 1 male and 1 female), in the CF group was 25% (*n* = 3, 3 males), and was 21.7% (*n* = 5) overall. Two male participants, one from each group, cited scheduling issues as their reason for dropping out of the study and one male from the CF group stated a lower body injury and groin pull during an exercise session as his reason for discontinuing the intervention. The other 2 participants (1 female from A-RT group, 1 male from CF group) did not cite or provide any reasons for dropping out of the study. Over 88% (*n* = 8) of A-RT participants felt that the intervention met their expectations, and 11.1% (*n* = 1) said it exceeded their expectations. Over 66% (*n* = 6) of participants in the CF group described the intervention as having exceeded their expectations, 22.2% (*n* = 2) as having met their expectations, and 11.1% (*n* = 1) as having not met their expectations on the posttest questionnaire, due to the fact that the participant expected to lose a desired amount of weight and did not reach that weight loss goal. The exercise intervention exceeded expectations of 67% (*n* = 6) members in the CF group due to the challenging nature of the CF workouts, the support and knowledge of the head CF coach, and the friendly competition between members in the CF group.

Participant Demographic Information

The average age of initial participants in the A-RT group was 28.0 ± 5.7 years with 72.7% (*n* = 8) of them being female, 36.4% (*n* = 4) married, and 45.5% (*n* = 5) employed. The average BMI calculated from height and weight measurements was 30.2 ± 3.4, placing them in the obese category. FPG levels averaged 87.2 ± 8.1 mg/dL, showing that the A-RT participants had normal fasting blood glucose. This information is displayed below in Table 4.1. The largest annual income category for A-RT participants was < $20,000 (37%, *n* = 4); 18.2% (*n* = 2) earned $20,001-$30,000, 18.2% (*n* = 2) earned $30,001-$40,000, and one participant each (9.1%) reported earning $50,001-$60,000, $60,001-$70,000, and > $100,000. The majority of A-RT participants were Caucasian (73%, $n = 8$), with a small percentage of minority races: Asian (18%, $n = 2$) and African American (9%, $n = 1$).

The average age of initial participants in the CF group was 28.3 ± 7.1 years with 41.7% ($n = 5$) of them being female, 58.3% ($n = 7$) married, and 58.3% ($n = 7$) employed. The average BMI calculated from height and weight measurements was 31.9 ± 3.5, placing them in the obese category. FPG levels averaged 88.4 ± 10.4 mg/dL, showing that the CF participants also had normal fasting blood glucose. This information is displayed below in Table 4.1. Half of the CF participants reported annual incomes of < $20,000 (50%, $n = 6$); one participant each (9.1%) reported earning between $20,001-$30,000, $30,001-$40,000, $40,001-$50,000, and $70,001-$80,000; 18.2% ($n = 2$) earned $80,001-$90,000. The CF group participants were either Caucasian (75%, $n = 9$) or Hispanic (25%, $n = 3$).

Table 4.1 Participant Demographic Information

	A-RT Group *n* = 11	**CF Group *n* = 12**
Age (SD)	28.0 (5.7)	28.3 (7.1)
% Female	72.7%	41.7%
% with Bachelor's Degree or Higher	54.6%	58.3%
% Married	36.4%	58.3%
% Employed	45.5%	58.3%
Height cm (SD)	169 (9.2)	170 (9.5)
Weight kg (SD)	85.8 (10.7)	92.8 (16.5)
Body Mass Index (SD)	30.2 (3.4)	31.93 (3.5)
Waist Circumference cm (SD)	93.6 (9.5)	102 (11.4)
Fasting Plasma Glucose mg/dL (SD)	87.2 (8.1)	88.4 (10.4)

Time Spent Exercising

The total time spent exercising (i.e., time spent in moderate physical activity) per week averaged 190.0 ± 10.7 minutes in the A-RT group. The total time spent exercising (i.e., time spent completing the WOD) per week averaged 38.7 ± 15.6 minutes in the CF group. The average time per workout session in the A-RT group was 63.3 ± 3.6 minutes and 13.1 ± 0.9 minutes for the CF group. The CF group spent significantly less time exercising per day ($t = 43.6$, $p < 0.001$) and per week ($t = 4.5$, $p = 0.001$) than the A-RT group. (*Note*: The time for the

A-RT included an average of 20 minutes of resistance training (range = 15-25 minutes), estimated based upon observations by the certified personal trainer working with the A-RT group during resistance training sessions.)

Baseline Measures

Table 4.2 shows the comparison values of baseline measures between groups. No statistically significant differences were found between groups for any measure taken at baseline.

Table 4.2 Between-Group Comparisons for all Pretest Baseline Measures

Measure	A-RT Group (SD) *n* = 9	CF Group (SD) *n* = 9	*t*	*p*-value
Glucose AUC	4061 (529)	4256 (700)	-0.64	0.53
FPG (mg/dL)	85.8 (6.6)	86.2 (10.4)	-0.11	0.92
40m Dash (sec)	7.8 (1.0)	7.1 (1.5)	1.12	0.28
Pushups Knees (#)	19.0 (4.0)	15.2 (5.3)	1.42	0.19
Pushups Toes (#)	19.0 (11.3)	25.0 (6.2)	-0.89	0.42
Situps (#)	21.3 (3.4)	20.6 (2.1)	0.59	0.56
Vertical Jump (cm)	30.5 (9.2)	39.2 (13.1)	-1.64	0.12
Broad Jump (cm)	155 (39.7)	162 (39.9)	-0.38	0.71
Sit and Reach (cm)	27.3 (9.1)	29.4 (39.4)	-0.47	0.64
Stork Balance (sec)	3.6 (1.7)	3.6 (2.3)	0.03	0.98
VO_2 Peak (mL/kg/min)	32.6 (7.5)	36.1 (9.2)	-0.91	0.38
Weight (kg)	86.1 (9.7)	86.6 (10.1)	-0.11	0.91
Waist Circumference (cm)	91.8 (8.8)	97.2 (7.0)	-1.45	0.17
Body Mass Index	30.1 (3.5)	30.9 (2.3)	-0.52	0.61
Body Fat %	43.5 (8.0)	40.6 (8.5)	0.73	0.48
Lean Body Mass (kg)	46.5 (9.3)	49.0 (10.4)	-0.54	0.60
Fat Mass (kg)	35.6 (7.1)	33.2 (6.7)	0.74	0.47

Tests of Hypotheses

Glucose Control

Glucose control was measured by calculating glucose AUC to test hypothesis 1. The average change in glucose AUC was +279 (405) for the A-RT group and -28.3 (577) for the CF group (Table 4.3 and Table 4.4). Neither change was statistically significant within groups: A-RT group (t = 1.95, p = 0.09), or CF group (t = -0.15, p = 0.89).

Table 4.3 Within A-RT Group Changes in Blood Glucose

A-RT Group *n* = 8	Pretest Mean (SD)	Posttest Mean (SD)	*t*	*p*-value
Glucose AUC	4061 (529)	4297 (733)	1.95	0.09

Table 4.4 Within CF Group Changes in Blood Glucose

CF Group *n* = 9	Pretest Mean (SD)	Posttest Mean (SD)	*t*	*p*-value
Glucose AUC	4256 (700)	4228 (581)	-0.15	0.89

Table 4.5 shows results from the ANCOVA conducted between-groups for changes in glucose AUC. There was no statistically significant difference between groups, $f(1) = 1.13$, $p = 0.31$.

Table 4.5 ANCOVA for Blood Glucose Changes Between-Groups

Δ in Variable	A-RT (SD) *n* = 8	CF (SD) *n* = 9	F	*p*-value
Δ in Glucose AUC	279 (405)	-28.3 (577)	1.13	0.31

Fitness Measures and Aerobic Capacity

Fitness measures and aerobic capacity were measured to test hypothesis 2. The A-RT group improved significantly on the number of pushups completed on their knees ($t = 3.06$, $p = 0.01$) (see Table 4.6).

Table 4.6 A-RT Within-Group Fitness Changes (*n* = 9)

A-RT Group	Pretest Mean (SD)	Posttest Mean (SD)	*t*	*p*-value
VO_2 Peak mL/kg/min	32.6 (7.5)	35.1 (7.8)	2.01	0.08
40m Dash (sec)	7.8 (1.0)	8.1 (1.1)	1.83	0.10
Pushups Knees (#)	19.0 (4.0)	23.6 (5.4)	3.66	***0.01***
Pushups Toes (#)	19.0 (11.3)	18.0 (7.1)	-0.33	0.80
Situps (#)	21.3 (3.4)	21.2 (4.0)	-0.11	0.92
Vertical Jump (cm)	30.5 (9.2)	30.2 (9.5)	-0.26	0.80
Broad Jump (cm)	155 (39.7)	158 (37.3)	0.73	0.49
Sit and Reach (cm)	27.3 (9.1)	27.0 (8.4)	-0.36	0.73
Stork Balance (sec)	3.6 (1.7)	4.6 (1.7)	1.45	0.19

The CF group improved significantly on VO_2 peak (9.1% increase, $t = 3.04$, $p = 0.02$), number of pushups done on knees ($t = 4.05$, $p = 0.02$), and situps ($t = 3.83$, $p = 0.01$), but had significantly slower times on the 40m dash ($t = 2.39$, $p = 0.049$) (see Table 4.7).

Table 4.7 CF Within-Group Fitness Changes (*n* = 9)

CF Group	Pretest Mean (SD)	Posttest Mean (SD)	*t*	*p*-value
VO_2 Peak mL/kg/min	36.1 (9.2)	39.4 (8.9)	3.04	***0.02***
40m Dash (sec) *$n = 8$	7.1 (1.5)	7.1 (1.3)	2.39	***0.049***
Pushups Knees (#)	15.2 (5.3)	21.2 (5.4)	4.05	***0.02***
Pushups Toes (#)	25.0 (6.2)	27.0 (7.5)	1.23	0.31
Situps (#)	20.6 (2.0)	22.0 (2.4)	3.83	***0.01***
Vertical Jump (cm)	39.2 (13.1)	39.1 (12.5)	-0.09	0.93
Broad Jump (cm)	162 (39.9)	174 (43.5)	1.87	0.10
Sit and Reach (cm)	29.4 (9.4)	32.2 (6.1)	1.43	0.19
Stork Balance (sec)	3.6 (2.3)	5.3 (2.8)	1.56	0.16

The ANCOVA analysis showed there were no statistically significant differences between groups for any fitness measure, as shown in Table 4.8.

Table 4.8 ANCOVA for Fitness and Aerobic Capacity Changes Between-Groups

Δ in Variable	A-RT (SD) *n* = 9	CF (SD) *n* = 9	F	*p*-value
Δ inVO_2 Peak	2.5 (3.7)	3.3 (3.2)	0.40	0.54
Δ in 40m Dash*	0.4 (0.6)	0.2 (0.3)	0.49	0.50
Δ in Pushups Knees	4.6 (3.3)	6.0 (3.3)	0.29	0.60
Δ in Pushups Toes	-1.0 (4.2)	2.0 (3.3)	1.13	0.37
Δ in Situps	-0.1 (3.1)	1.4 (1.1)	1.60	0.23
Δ in Vertical Jump	-0.3 (3.2)	-0.1 (4.8)	0.18	0.68
Δ in Broad Jump	3.0 (12.3)	12.1 (19.5)	1.51	0.24
Δ in Sit and Reach	-0.1 (1.1)	1.1 (2.3)	4.56	0.05
Δ in Stork Balance	1.0 (2.1)	1.7 (3.3)	0.37	0.55

*40m Dash $n = 8$

Body Composition

Body composition measurements were used to test hypothesis 3. Neither group experienced any significant within-group changes in body composition as shown by Tables 4.9 and 4.10. The ANCOVA analysis also showed no statistically significant differences between groups for changes in body composition (see Table 4.11).

Table 4.9 A-RT Within-Group Body Composition Changes

A-RT Group *n* = 9	**Pretest Mean (SD)**	**Posttest Mean (SD)**	***t***	***p*-value**
Body Fat %	43.5 (8.0)	43.2 (8.3)	-0.57	0.58
Lean Body Mass (kg)	46.5 (9.3)	46.5 (10.1)	0.10	0.92
Fat Mass (kg)	35.6 (7.1)	35.0 (6.9)	-1.11	0.30

Table 4.10 CF Within-Group Body Composition Changes

CF Group *n* = 9	**Pretest Mean (SD)**	**Posttest Mean (SD)**	***t***	***p*-value**
Body Fat %	40.6 (8.5)	39.6 (9.1)	-2.04	0.08
Lean Body Mass (kg)	49.0 (10.4)	49.5 (10.3)	1.41	0.20
Fat Mass (kg)	33.2 (6.7)	32.1 (7.3)	-1.80	0.11

Table 4.11 ANCOVA for Body Composition Changes Between-Groups

Δ in Variable	**A-RT (SD) *n* = 9**	**CF (SD) *n* = 9**	**F**	***p*-value**
Δ in Body Fat %	-0.3 (1.7)	-1.1 (1.6)	0.66	0.43
Δ in Lean Body Mass	0.1 (1.6)	0.6 (1.2)	0.40	0.54
Δ in Fat Mass	-0.6 (1.5)	-1.0 (1.7)	0.32	0.58

Chapter 5 - Discussion

The novel purpose of this study was to compare any changes in glucose control, fitness (Eurofit and peak aerobic capacity), and body composition (body fat percentage, fat mass, and lean body mass) between a standard aerobic and resistance exercise training program (A-RT) and a shorter-duration, high-intensity CF training program in overweight and obese physically inactive adults. The CF intervention was chosen as an exercise protocol that combined A-RT elements performed at a relatively high intensity to determine if it elicited greater improvements in glucose control, fitness, and body composition. The principal findings of this study were that 8 weeks of exercise training resulted improvements to muscular endurance within the CF and A-RT groups (pushups on knees in both groups and situps in the CF group), and improvements in peak aerobic capacity within the CF group. However, no changes in glucose control were seen in either group.

Hypothesis 1 stated that both the A-RT and CF exercise groups would improve glucose control with the CF group improving significantly more than the A-RT group. This hypothesis was not supported. Similar to previous studies, glucose control did not change significantly for either group (2, 3). For example, an 8-week endurance-training study found no effects on fasting blood glucose concentration post-training (2). No changes to postexercise glucose levels were exhibited in normal or glucose-intolerant adults after one bout of resistance training (6). Similarly, training had little effect on glucose response in adults and elderly subjects following 12 weeks of resistance training (3).

The lack of any changes seen in glucose control in either group could be due to the shorter 8-week duration of the intervention. Twelve weeks of aerobic exercise has been shown to improve insulin sensitivity in overweight or obese adults (14, 18), as well as 16 weeks of aerobic exercise (9). Previous research has shown improvements to glucose control and insulin sensitivity with 16 weeks of resistance training (11, 22). Likewise, previous research has shown improved insulin sensitivity with 16 weeks of combined aerobic and resistance training (27), and 24 weeks of aerobic and resistance training done at a higher intensity (21).

Hypothesis 2 stated that both the A-RT and CF exercise groups would improve fitness, with the CF group improving significantly more than the A-RT group. Hypothesis 2 was partially supported. Previous exercise studies have found similar improvements to aerobic capacity, with the greatest increases resulting from shorter duration, high-intensity training (13, 26). A combination of aerobic and resistance training has also been shown to improve aerobic capacity (17). Similar improvements to muscular endurance and flexibility were found in a military population comparing an 8-week HIFT circuit-training protocol to a standard Army training protocol (12).

Hypothesis 3 stated that both the A-RT and CF exercise groups would demonstrate decreases in body fat percentage and fat mass and increases in lean body mass, with the CF group improving significantly more than the A-RT group. This hypothesis was not supported, either. The results of this study show that body composition did not change significantly within or between groups. Eight-weeks of HIFT in active duty military also found no apparent changes in body composition (12). Again, a longer study might have found changes, as 16 weeks of aerobic training found decreased fat mass post training (9), and a 12-week high-intensity aerobic study found decreased fat mass after training (18). Significant increases in lean body mass and decreases in fat mass were experienced after 12 weeks of resistance training (3), and improvements to lean body mass and decreases to body fat percentage were seen after 16 weeks of resistance training (22). Significant decreases in fat mass have been shown after 15 weeks of HIIE (28).

Strengths

This is the first study to systematically study the effects of a CF HIFT-style exercise intervention on health indicators, fitness measures, peak aerobic capacity, or body composition in an overweight and obese physically inactive population. The workouts completed by CF participants were actual CF workouts programmed by a certified CF instructor using the CF methodology. Participants in both groups were statistically similar at baseline in all categories; changes seen in posttest measures were the direct result of the exercise intervention. The results of this study are the first to show that a short duration, high-intensity strength and conditioning program such as CF, that temporally combines A-RT movements, can result in improvements in muscular endurance and peak aerobic capacity. Highly skilled CF L2 and L1 coaches were used for the CF training sessions and an ACE certified personal trainer was used to monitor and oversee the resistance training sessions for A-RT participants.

Multiple measurements of body composition were conducted, including measured height and weight to calculate BMI, measured waist circumference and DEXA scan. DEXA scans are regarded as an accurate and reliable body composition testing method (16).

Limitations

Previous exercise training studies investigating glucose control and insulin sensitivity used a protocol of two hours for an OGTT (27), and this study only used the one-hour protocol due to limited time and financial constraints. Information gathered from a full two hour OGTT would also have allowed each individual participant to be categorized as having normal glucose control, prediabetic, or diabetic glucose levels (32).

Other fitness measures besides the valid and reliable Eurofit measures could have been administered. Absolute strength could have been assessed with a 1-RM for specific upper and lower body lifts for both groups. VO_2 peak is not as accurate a representation of aerobic capacity as VO_2 max. Administering a direct VO_2 max with validation would have given a true measure of maximal aerobic capacity. Some participants chose to end the VO_2 peak test early due to self-reported physical discomfort from the required head support and breathing apparatus (mouthpiece).

The lack of significant changes in body composition may be attributed to the fact that diet was neither controlled nor assessed for each participant. A 16-week aerobic exercise study of moderate-intensity physical activity at 60-75% heart rate max (HR max) combined with caloric reduction in obese non-diabetic participants significantly improved insulin sensitivity and fat oxidation (9). The type of diet and caloric consumption by each participant would play a large role in the resulting body composition during the intervention. Dietary intake of participants before, during, and after the intervention may have changed, which may have impacted body composition results. In the future, assessment of food intake could be measured with a 3-day food log at baseline and post-training.

Menstrual cycles of female participants were not accounted for during glucose testing. Insulin sensitivity has been found to decrease during the follicular phase of a woman's menstrual cycle and impaired during the luteal phase (4). Glucose control could have been impaired during FPG and OGTT tests as a result of the specific phase of the menstrual cycle in female participants.

The DEXA was inoperable the week following the completion of the intervention. Scans were unable to be completed until 2 weeks following intervention completion. Training cessation has been shown to decrease fatty acid oxidation (20), and if participants remained inactive for the 2 weeks following the intervention and maintained normal dietary intake, body composition could have been altered.

Although participants were asked to refrain from any extra physical activity outside of the intervention and scheduled workout times, participants in both groups admitted to engaging in extra physical activity outside the intervention as indicated on posttest surveys. For example, one participant in the A-RT group claimed to have participated in a 10K running race and also claimed to have gone on a 60-mile bike ride one weekend. Participants in the CF group admitted to participating in extra runs during the week outside of the intervention.

Future Research

Future research could utilize a larger sample with T2DM to test the effects of a longer duration CF exercise intervention on glucose control and insulin sensitivity. A 2-hour OGTT could also be administered to get a direct assessment of glucose control and peripheral insulin action and sensitivity. A nutrition intervention could also be administered in conjunction with a CF exercise intervention in the hopes of eliciting changes to body composition in those participating.

Conclusion

Obesity has become a major health care issue in the US today and is one of the major factors leading to T2DM (23). T2DM affects millions of Americans and the number of diagnosed cases is increasing each year. The ACSM and ADA have created exercise guidelines to help prevent T2DM, but the majority of Americans do not achieve the recommended amount of exercise per week, especially those who are sedentary and overweight or obese (1, 34). High-intensity training that incorporates a combination of A-RT may be an appropriate exercise prescription for obese populations at risk for T2DM, but more research on a larger scale is needed to provide evidence of the potential health benefits of A-RT done at a higher intensity. The results of this study show that eight weeks of A-RT or CF training did not yield significant changes in glucose control or body composition in overweight or obese adults. However, despite exercising significantly less time per week CF training demonstrated greater improvements in fitness measures than A-RT.

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Appendix A - Glossary of Acronyms

Glossary of Terms/Acronyms

1-RM- One-repetition maximum

A-RT- Aerobic and resistance training

ACE- Amercan Council on Exercise

ACSM- American College of Sports Medicine

ADA- American Diabetes Association

ANCOVA- Analysis of covariance

AUC- Area under the curve

BMI- Body mass index

CF- CrossFit

CVD- Cardiovascular disease

DEXA- Dual energy X-ray absorptiometry

ERT- Endurance resistance training

FPG- Fasting plasma glucose

HIFT- High-intensity functional training

HIIE- High-intensity intermittent exercise

HIIT- High-intensity interval training

HR max- Heart rate max

HRR- Heart rate reserve

IGT- Impaired glucose tolerance

IRB- Institutional review board

MRT- Maximal resistance training

NIDDM- Non-insulin dependent diabetes mellitus

OGTT- Oral glucose tolerance test

RER- Respiratory exchange ratio

T2DM- Type 2 diabetes mellitus

VO_2 max- Maximal aerobic capacity

VO_2 peak- Peak aerobic capacity

WOD- Workout of the day

Appendix B - CrossFit Workouts

Summary and List of all CF Workouts Completed

Table B.1 Full List of All CF Workouts and Modalities Included

Day 1
Elements Tutorial

Day 2
Elements Tutorial

Day 3	**Monostructural**	**Gymnastics**	**Weightlifting**
3 Rounds For Time			
10 MedBall Cleans			x
10 Burpees		x	
or			
3 Min As Many Rounds As Possible			
3 MedBall Cleans			x
3 Burpees		x	

Day 4	**Monostructural**	**Gymnastics**	**Weightlifting**
3 Rounds For Time			
7 Handstand Pushups		x	
9 Pullups		x	
11 Squats		x	

Day 5	**Monostructural**	**Gymnastics**	**Weightlifting**
10 Hang Squat Cleans			x
10 Kettlebell Swings			x
10 Box Jumps	x		

Day 6	**Monostructural**	**Gymnastics**	**Weightlifting**
10 Min As Many Rounds As Possible			
10 Ball Slams			x
10 Pullups		x	
then			
10 Min As Many Rounds As Possible			
10 Kettlebell Sumo Deadlift High Pull			x
10 Handstand Pushup		x	

Day 7	**Monostructural**	**Gymnastics**	**Weightlifting**
10 Burpee Deadlift			x
20 Push Press			x
30 Jump Rope	x		

Day 8	**Monostructural**	**Gymnastics**	**Weightlifting**
10-8-6-4-2			
1 arm Dumbbell Overhead Squat			x
Situps		x	
Pushups		x	

Day 9	**Monostructural**	**Gymnastics**	**Weightlifting**
3 Rounds For Time			
400m Run	x		
21 Kettlebell Swings			x
42 Situps		x	

Day 10	**Monostructural**	**Gymnastics**	**Weightlifting**
2 Rounds For Time			
7 Muscle Up Transitions		x	
30 Mountain Climbers	x		
3 Overhead Squats			x
6 Front Squats			x
9 Back Squats			x
30 Mountain Climbers	x		
12 Handstand Pushups		x	

Day 11	**Monostructural**	**Gymnastics**	**Weightlifting**
3 Rounds Max Reps			
1 Min Dumbbell Snatch			x
30 sec Rest			
2 Min Front Squats			x
30 sec Rest			
1 Min Dumbbells Snatch			x
30 sec Rest			

Day 12	**Monostructural**	**Gymnastics**	**Weightlifting**
10 Rounds For Time			
8 Burpees		x	
3 Bleacher Runs	x		

Day 13	**Monostructural**	**Gymnastics**	**Weightlifting**
5 Rounds For Time			
4 Handstand Pushups		x	
80 yds Plyo Skip	x		
25 Good Mornings			x

Day 14	**Monostructural**	**Gymnastics**	**Weightlifting**
For Distance			
12 Min Run	x		

Day 15	**Monostructural**	**Gymnastics**	**Weightlifting**
20 Min As Many Rounds As Possible			
10 Toes To Bar		x	
3 Strict Pullups		x	
13 Deadlifts			x

Day 16	**Monostructural**	**Gymnastics**	**Weightlifting**
400m Run	x		
then			
2 Rounds For Time			
40 Kettlebell Swings			x
20 Slapping Pushups		x	
20 KB Thrusters Alternating			x
then			
400m Run	x		

Day 17	**Monostructural**	**Gymnastics**	**Weightlifting**
10 Min As Many Rounds As Possible			
5 Pullups		x	
5 Handstand Pushups		x	
then			
10 Min As Many Rounds As Possible			
5 Floor Wipers		x	
5 Dips		x	

Day 18	**Monostructural**	**Gymnastics**	**Weightlifting**
5 Rounds For Time			
10 Snatch Balance			x
20 Ball Slams			x
30 Mat Broad Jumps	x		

Day 19	**Monostructural**	**Gymnastics**	**Weightlifting**
4 Rounds For Time			
80-60-40-20 Jump Ropes	x		
12 Burpees		x	
10-15-20-25 MedBall Cleans			x

Day 20	**Monostructural**	**Gymnastics**	**Weightlifting**
10x2 Box Squat			x
8x2 Deadlifts			x
then			
5 Min Overhead Squats			x

Day 21	**Monostructural**	**Gymnastics**	**Weightlifting**
3 Rounds For Time			
15 Shoot-throughs		x	
15 Divebomber Pushups		x	
400m Run	x		

Day 22	**Monostructural**	**Gymnastics**	**Weightlifting**
4 Rounds For Time			
30 Mountain Climbers	x		
20 Mod L-sit Raises		x	
10 Sotts Press			x

Day 23	**Monostructural**	**Gymnastics**	**Weightlifting**
12x60 yd Sprint	x		
5 Min Jump Rope	x		

Day 24	**Monostructural**	**Gymnastics**	**Weightlifting**
3 Rounds For Reps			
1 Min Wallballs			x
1 Min Sumo Deadlift High Pulls			x
1 Min Box Jumps	x		
1 Min Push Press			x
1 Min Row	x		
1 Min Rest			