Spring 5-7-2021

Effect of Single vs Accumulated Bouts of Exercise on Body Composition, Fitness, and Resting Metabolic Rate

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EFFECT OF SINGLE VS ACCUMULATED BOUTS OF EXERCISE ON BODY COMPOSITION, FITNESS, AND RESTING METABOILIC RATE

By

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Presented to the Faculty of the Graduate School of

Stephen F. Austin State University

In Partial Fulfillment

Of the Requirements

For the Degree of

Master of Science in Kinesiology

STEPHEN F. AUSTIN STATE UNIVERSITY

May, 2021

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ABSTRACT

Obesity and physical inactivity are two factors that have been shown to be correlated with cardiovascular disease (CVD) and diabetes. As people have increasingly busier schedules, they have less time to commit to exercise. Accumulating exercise in small bouts is a schedule-friendly alternative to longer continuous bouts of exercise and may protect against CVD and diabetes. Therefore, the purpose of this study was to examine the effects of accumulated exercise compared to continuous exercise on body composition, fitness, and resting metabolic rate. Nine healthy male (n=4) and female (n = 5) volunteers were randomized into either an accumulated intervention group consisting of two bouts of exercise per day, a continuous intervention group consisting of one bout exercise per day, or a control group consisting of no exercise. Both exercise groups performed 30 minutes of Tabata exercise three times per week for 4 weeks. Participants were assessed for body composition, cardiovascular fitness, and resting metabolic rate at the beginning of the study and again at 4 weeks. Significant differences were only found when comparing within groups pre- and post-intervention for body fat percent in the 2-bout group ($p = 0.03$; ES = - 0.63). Continuous and accumulated Tabata exercise had no effect on cardiovascular fitness or resting metabolic rate.

Keywords: Tabata, Intermittent Exercise, Short Bouts, HIIT, VO2 max, Calisthenics, Training.

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INTRODUCTION

The predominance of cardiovascular disease (CVD) and diabetes mellitus has dramatically increased in recent years. Cardiovascular disease was the leading cause of death in 2017 while diabetes was the seventh leading cause (9). Cardiovascular disease refers to numerous issues such as heart attack, stroke, congestive heart failure, and atherosclerosis. Diabetes Mellitus is a risk factor for CVD and is characterised by a partial or complete deficiency of insulin secretion, decreased insulin sensitivity, impaired food substrate metabolism, and hyperglycemia. There are two main types of diabetes. Type 1 diabetes is a type of autoimmune disease that results in the destruction of islet cells in the pancreas and, consequently, a reduced ability to produce insulin. People with type 1 diabetes are insulin dependent. Individuals with Type 2 diabetes (T2D) are not insulin dependent but are insulin resistant. This resistance to insulin is the result of chronically high levels of insulin secreted into the blood in response to high concentrations of blood glucose after meals which, over time, lead to the down-regulation of insulin receptors. Type 2 diabetes is the most common form of diabetes (12).

Body composition is the amount of fat mass relative to lean mass, represented as percent body fat. Although there are no globally recognized norms for body composition, according to the American College of Sports Medicine (ACSM), a body composition of 10% - 22% for men and 20% - 32% for women is viewed as healthy (19). An excessive amount of body fat is strongly associated with CVD and diabetes mellitus (11, 18). Additionally, physical inactivity is associated with higher amounts of body fat (13). Therefore, it is important to avoid being physically inactive and to improve body composition since they are correlated with CVD and diabetes.

Resting metabolic rate (RMR) is the amount of energy your body expends while at complete rest. This energy is used for vital functions such as breathing, blood circulation, and the growth and repair or cells and can be affected by things such as the thermic effect of food and physical activity (5). Resting metabolic rate represents the majority of daily caloric expenditure (23). Weight loss is necessary for reducing the risk of developing CVD or diabetes in overweight or obese individuals and is primarily induced by a negative energy balance (8). Energy balance is the budgeting between the energy consumed through food and energy expended by the body (3). Consuming more energy than what is expended by the body is referred to as a positive energy balance and consuming less energy than the body expends is called a negative energy balance. Since RMR is the greatest contributor to daily energy expenditure, increasing RMR can potentially facilitate the negative energy balance required for weight loss and, thus, may benefit overweight or obese individuals.

A lack of time is reported as the primary reason why people do not exercise (25). The ACSM recommends that people do either 150 minutes of moderate intensity exercise per week or 75 minutes of high intensity exercise per week to gain CVD preventing benefits (19). The amount of moderate intensity exercise can be broken up into 30-minute sessions, 5 days per week. Additionally, a joint statement by the Centers for Disease Control and the ACSM has stated that people can accumulate their daily 30 minutes of exercise in short bouts throughout the day (16). Breaking up exercise into smaller bouts throughout the day could be a beneficial strategy for people who cannot commit a large amount of time towards exercise due to their busy schedules.

Tabata exercise is a type of calisthenic exercise which does not require exercise equipment, access to a gym, or a large amount of space to move around. Tabata exercise, which was first illustrated by Tabata et al. (24), is typically done in either high intensity or supramaximal intensity intervals. The intervals in Tabata usually consist of 20-second bouts of exercise interspersed with 10 seconds of rest between each bout. Tabata workouts typically utilize bodyweight exercises such as burpees, push ups, jumping jacks, and abdominal exercises. Although Tabata is a popular form of exercise, little is known about the effects of Tabata and accumulated exercise on body composition and resting metabolic rate. Most studies that compare continuous exercise and accumulated exercise utilize modes of exercise such as walking, jogging, or some other form of aerobic exercise. The purpose of this study was to compare the effects of Tabata either done as a single continuous bout or shorter accumulated bouts on body composition, fitness, and resting metabolic rate.

REVIEW OF LITERATURE

Effects of continuous exercise versus accumulated exercise on body composition.

Chung et al. (6) investigated the effects of continuous bouts of exercise compared to multiple short bouts of exercise on the risk for metabolic syndrome. In this 12-week, controlled study, 36 middle-aged women were placed into either a continuous exercise (CONT) group, an accumulated exercise (ACC) group, or a control group (CON). Both exercise interventions were done 3 days per week on a treadmill. The CONT group did 30 minutes of uninterrupted walking at 83% Vo2 Max. The ACC group performed three 10-minute bouts of walking at the same intensity with at least 4 hours between each session. The CON group did not do any exercise. All of the participants were instructed to reduce their caloric intake by 300 kcal. Body composition was measured using bioelectrical impedance analysis (BIA) both pre and post-intervention. The participants in the CONT group had a significant reduction in fat mass post-intervention ($P < 0.01$) but not for the ACC group. The researchers speculated that 8 weeks may not be a long enough time to see improvements in body composition for accumulated exercise. That said, both the CONT and ACC groups had significant improvements in waist circumference ($P < 0.001$ for both groups) post-intervention. The results of this study suggest that continuous exercise was more effective than accumulated exercise at reducing body fat mass (6).

Osei-Tutu & Campagna (15) investigated the effects of continuous compared to accumulated bouts of exercise on mood, Vo2 max, and percent body fat. In this 8-week randomized controlled trial, 40 healthy sedentary men and women were randomized into either a CONT group, an ACC group, or a CON group. The CON group remained sedentary and did not perform any lifestyle changes. Both of the exercise groups performed exercise in the form of brisk walking for 30 minutes per day 5 days per week at an intensity of 60%-79% of their max heart rate. No other physical activity was done outside of the exercise intervention. The ACC group performed three separate 10 minute bouts of brisk walking throughout the day. The 10-minute bouts were separated by at least 2 hours between each bout. Body composition was measured using skin fold measurements. The study did not mention if the diets of the participants were controlled or not, therefore it can be assumed that the participants did not change their normal nutritional habits for the duration of the study. The researchers found that body fat was significantly reduced in the CONT group ($P \leq 0.05$) but not in the ACC or CON groups. The researchers did not discuss the possible reasons for the lack of change in body composition for the ACC group. One reason there might have been a lack of change in body composition is that the participants were not particularly overweight at baseline. The females had a mean body fat percentage of 28.5 ± 1.3% at baseline which is within the healthy range. The males had a mean body fat percent of 23.9 ± 1.3% at baseline which is just above the healthy range. Thus, there was not a vast amount of room for improvement. Based on the findings of this study, the researchers were able to conclude that continuous exercise was more effective than accumulated exercise at improving body composition (15).

Rodriguez-Hernandez & Wadsworth (20) compared the effects of continuous and intermittent walking on body composition. In this 10-week randomized controlled study, 68 sedentary office employees were assigned randomly to either a CONT group, an ACC group, or a CON group. In the CONT group's intervention involved a gradually progressing walking intervention at an intensity of 30-60% of maximum heart rate, for 20-40 minutes per day, 3-5 days per week. The ACC group's intervention consisted of walking at the same incremental intensity, frequency, and duration but they performed the exercise in 5 minute bouts throughout the day. The researchers noted that the walking intensity and total time spent walking was matched between groups. The CON group was not prescribed any exercise. The normal dietary habits of the participants were not changed for the duration of the study. Body composition was measured using DEXA. After the 10-week walking intervention, all 3 groups significantly decreased in both fat mass and body fat percentage. Lean mass was significantly increased in the ACC and CON groups, but not he CONT group. Also, body fat was reduced in all 3 groups. Participants in the control group increased in lean mass and decreased in fat mass. This may have been because the researchers did not control for physical activity in the control. It was stated in the article that physical activity in the CON group increased. The researchers in this study concluded that a continuous walking intervention was effective at producing positive changes in body composition. They also concluded that accumulated exercise produced similar benefits towards body composition as continuous exercise (20).

Alizadeh et al. (1) compared the effects of intermittent and continuous aerobic exercises, along with caloric restriction, on body composition. In this 12-week randomized controlled study, 31 overweight or obese women aged 20-45 years old were randomized into either a CON, CONT, or ACC group. The CON group resumed their regular physical activities for the duration of the study. The CONT group was instructed to perform aerobic exercises such as brisk walking for 40 minutes 5 days per week at an intensity of 64%-76% max heart rate. The ACC group was instructed to perform 3 separate bouts of the same exercises such that the total time spent exercising added up to 40 minutes. The ACC group performed these exercises 5 days per week at the same intensity as the CONT group. The researchers also requested that the ACC group separate their exercise bouts by at least 4 hours. Body composition was measured using skin fold measurements and BIA. All of the participants were instructed to reduce their daily caloric intake by 500 kcals. Both the body mass index (BMI) and the weight of the participants in the ACC group decreased significantly when compared to the CONT group. The participants in the CON group also showed a decrease in weight and BMI, presumably due to the caloric restriction. When CON was compared to the CONT and ACC group, there were no significant differences between groups. Measures in skin fold measurements and body fat percentage was not significantly different between any of the groups. The researchers in this study concluded that although there was no difference in weight loss or reduction of BMI between the CON and the exercise groups, accumulated exercise produced greater positive effects on BMI and weight than continuous exercise (1).

A study by Jakicic et al. (10) observed the effects of single continuous bouts of exercise compared to accumulated bouts of exercise on weight loss and cardiorespiratory fitness. In this 20-week randomized study, 56 overweight or obese women were randomized into a CONT group or an ACC group. The CONT intervention consisted of a single bout of aerobic exercise 5 days per week. The amount of time progressed over the course of the study from 20 minutes to 40 minutes per day. The ACC group performed multiple 10-minute bouts of the same exercises. The total time spent exercising was matched between groups. The researchers found that there was a trend for accumulated exercise to be more effective at eliciting weight loss than continuous exercise (P = 0.07). They also found that accumulated bouts enhanced exercise adherence. Based off of the results of this study, the researchers concluded that, due to the increased exercise adherence and trend towards significantly enhanced weight loss, accumulated exercise may be preferred over continuous exercise (10).

Effects of Tabata on body composition.

Murawska-Cialowicz et al. (14) focused on the effects of the Tabata protocol (TAB) compared to a control on body composition, irisin concentration, and aerobic and anaerobic performance in men. In this 8-week randomized controlled training study, 25 men with low levels of physical activity were randomized into either a high intensity TAB or a CON group. The TAB group performed 40 minutes of Tabata exercise along with an additional 10 min warm up and a 10 min stretching cool down twice a week. Each Tabata workout consisted of eight 4-minute exercise sessions. Each session consisted of alternating bouts of 20-second high intensity calisthenics and 10-seconds of recovery. Each session was separated by 1 minute of passive recovery. The participants were also instructed to perform each exercise at maximum effort. The CON group did not participate in any exercise. Body composition was measured using ultrasound. The study did not mention whether the diets of the participants were controlled or not, therefore it can be assumed that the participants did not alter their normal dietary habits. After the 8-week intervention, the researchers found a significant reduction in body fat percent in the TAB group when compared to pre-intervention ($P < 0.05$). There was no significant change in body fat percent in the CON group when compared to pre-intervention. Additionally, the researchers found a significant increase in lean body mass in the TAB group when comparing post 8-week to pre 8-week intervention ($P = 0.047$). As for the CON group, there was a significant decrease in lean body mass when comparing post-intervention to pre-intervention ($P = 0.047$). From the results of this study, the researchers were able to conclude that continuous, high intensity Tabata exercise is effective in improving body composition (14).

Domaradzki et al. (7), examined the effects of Tabata training on body composition, aerobic capacity, and anaerobic performance in overweight adolescents. In this 10-week trial, 58 sixteen-year-old students were placed into groups based on their body composition. There was an underweight group, an overweight group, and a group made up of normal weight students. All the groups went through a Tabata intervention in place of their physical education class once a week for one semester. The TAB intervention consisted of three 4-minute sessions of maximum intensity calisthenic exercise intervals. The intervals included 20 seconds of maximum intensity exercise followed by 10 seconds of active recovery. There were 1-minute passive recovery bouts between each 4-minute session. The students performed the Tabata exercises while following along with an instructional video during class. The physical education class met 3 times per week so the two remaining lessons for the week consisted of the normal physical education curriculum that was adopted by the school. The researchers asked the participants not to change their normal diet. Body composition was measured before and after the intervention using BIA. There were significant improvements in body fat percent for only the participants in the overweight group ($P < 0.001$). From the results of this study, it can be concluded that a continuous bout of maximum intensity Tabata exercise is efficient in improving body composition in overweight adolescents (7).

Bermejo et al. (2), investigated the effects of two different HIIT interventions (somewhat similar to Tabata) on body composition and performance. In this 4-week randomized trial, 14 men aged 21.67 ±1.61 years old were randomized into either a cycling group or a functional training group. The cycling intervention consisted of four 30-second exercise bouts separated by 3-minute bouts of recovery. The cycling was done at a cadence of 100-120 revolutions per minute at a workload that was 100 watts over their mean power output (MPO). The MPO was measured during an anaerobic power test that was conducted at the beginning of the study. The anaerobic power test was comprised of cycling at maximal effort for 60 seconds. During the test, resistance was reduced as time went on to keep cadence above 120 revolutions per minute. The functional training group performed 3 circuits of body weight exercises that included burpees, squats, battle ropes, 10-12 kg kettlebell swings, and agility ladder exercises. The exercises were performed for 30 seconds at maximal effort with 15 seconds between each exercise. Each circuit contained 6 different exercises and was separated by 3 minutes of rest. Both groups performed exercise twice per week. The volume of exercise was from 4 bouts to 6 bouts for the cycling sprints and from 3 circuits to 6 circuits for the functional training during the last 2 weeks of the study. The participants were asked not to alter their diet. Body composition was measured using skin fold measurements and there was a significant improvement in body fat percentage for both groups. Based off of these results, it can be concluded that the 2 different modes of HIIT were effective at improving body composition of healthy men (2).

Effects of Tabata on resting metabolic rate.

Pearson et al. (17) investigated the effects of Tabata exercise on resting and postprandial fat oxidation. In this acute randomized crossover study, eleven recreationally active males aged 23 ± 2.68 years old were randomized into either a TAB group or a CON group. After completion of their assigned 2-day intervention, the participants completed the alternate intervention. During each 2-day intervention, the exercise protocol was completed on the first day while on the second day, the participants were given a high fat meal and postprandial blood samples were taken. The TAB protocol involved 20 minutes of exercise made up of 4 sessions of exercises performed at a high intensity. The exact intensity was not mentioned, but power output for the intervention was measured using kinematic power calculations. Each session consisted 8 intervals of 20 seconds of exercise separated by 10 seconds of rest. There was 1 minute of rest between each session. The exercises utilized for the TAB protocol included rowing on a rowing ergometer, kettlebell swings, dumbbell thrusters, and burpees. During the CON protocol, the participants were instructed not to perform any exercise. The RMR of the participants was measured at the beginning of the second day before they were given their high fat meal and again at 60, 120, and 180 minutes after ingesting the high fat meal. At each time point, RMR was measured for 20 minutes using a metabolic cart. The researchers found a significant positive correlation between average power output and 1-hour postprandial RMR ($P = 0.049$). They also found a significant increase in fat oxidation in the TAB intervention when compared to control in the fasted state ($P = 0.010$), and at 1-hour ($P = 0.005$), 2-hours ($P = 0.013$), and 3-hours postprandial ($P = 0.017$). Based on these results, the researchers concluded that a Tabata-like pattern of exercise utilizing functional exercises was effective at increasing next-day postprandial fat oxidation and 1-hour postprandial RMR (17).

METHODS

Participants

Nine healthy, mildly active male (n = 4) and female (n = 5) volunteers (ages 18-44) were recruited to participate in this study. Mildly active was defined as no more than 60 minutes per week of moderate physical activity over the previous six months. Subjects had no known history of disease, were non-smokers, and were not on any diet or medications recommended for weight loss.

Study Design

For this randomized control study, the volunteers were requested to engage in either: 1) no exercise (Control), 2) one bout of exercise for 30 minutes (1-bout), or 3) two separate bouts of exercise (15 minutes each) for a total of 30 minutes (2-bout). Both exercise protocols included the use of an exercise known as TABATA. TABATA utilizes body calisthenics without the need for specialized equipment while being performed at high intensity. Participants were randomly selected to perform one of the three protocols and were requested to perform the protocol three times a week for 4 weeks. For the 1-bout protocol, TABATA was performed for 30 minutes. The 1-bout was performed at the participants' discretion either during the morning or afternoon. For the 2-bout protocol, TABATA was performed for 15 minutes during the morning and was repeated during the afternoon. Participants performing the 2-bout protocol were asked to wait 4 – 8 hours between exercise sessions. For the control session, participants did not exercise. All participants had their body composition, cardiovascular fitness, and metabolic rate assessed: 1) before the start of the study and 2) after four weeks of participation in the study.

Preliminary Measurements: The study consisted of 4 separate days of preliminary assessments. Day 1 consisted of the participants reviewing the informed consent, medical history form, research protocol, and signing approval to participate in the study. Prior to any participation in this study, participants were required to read and sign the informed consent and pre-participation screening questionnaire developed by the research staff. Participants were verbally informed of their rights and voluntary participation in this study as designated by the Stephen F. Austin State University IRB. Anthropometric data was also be gathered on all participants including age, height, weight, body mass index (BMI), and body composition using a dual energy x-ray (DXA) scans using a Lunar Prodigy densitometer.

On a separate day (day 2), participants performed a graded exercise test (GXT) on a treadmill for determination of the participants' maximal oxygen consumption (VO_2max). The GXT was performed on a motorized treadmill using the Bruce protocol.

After a brief warm up, the GXT started and continued through each stage until one of the following occurred: 1) participants' reached their VO_2max, 2) participants' achieved a respiratory exchange ratio of 1.1 or greater, 3) participants' achieved age-predicted heart rate max, 4) participants' voluntarily stopped exercising, or 5) participants' could no longer maintain the required workload for that particular stage.

Heart rate (HR) was monitored throughout the GXT. To estimate the individuals VO_2max during the GXT, each individual's expired air was collected continuously during the test using an open spirometry technique on a ParvoMedics True Max 2400 Oxygen Uptake system. The HR and VO_2 values from the GXT were used to develop a HR/VO_2 regression curve. This regression curve was be used to estimate the volunteers' energy expenditure when they perform the control, 1-bout, or 2-bout protocol based on the participants' HR during the performance of those protocols.

On day 3, participants' were instructed on how to properly perform the TABATA protocol. Following the instruction, the participants performed a familiarization trial for the TABATA protocol. The TABATA protocol consisted of 6 sessions with each session separated by 1 minute of active rest in the form of casual walking. Each session was comprised of 2 rounds with each round consisting of 4 movements. Each movement was performed at near maximal effort for 20-seconds followed with 10-seconds of rest. The complete TABATA protocol was 30 minutes, including a 5-minute warmup for a total time of 35 minutes.

On day 4, participants completed an assessment of their basal metabolic rate (BMR). Prior to beginning the BMR, the volunteers were asked to fast for a minimum of 10 hours. The volunteers were asked to arrive at the laboratory in the morning at approximately 8am and to void their bladder prior to beginning the BMR assessment. For the BMR, the volunteers rested in a reclined position for approximately 30 minutes. During the 30 minutes, the volunteers expired air was collected continuously using an open spirometry technique on a ParvoMedics True Max 2400 Oxygen

Uptake system. The expired air was used to estimate the volunteers metabolic rate represented by their VO_2. Approximately one week after the basal metabolic rate was assessed, the study began.

Experimental Protocols

Participants in the "control" group continued to follow their normal daily activities (same as what they were doing prior to starting this study) with no participation in any strenuous physical or structured exercise. This continued for 4 weeks. Participants in the "1-bout" group performed TABATA 30 minutes. Participants in the "2-bout" group performed 2 separate bouts of exercise (one bout in the morning and one bout in the afternoon). One bout of exercise involved performing TABATA sessions 1 through 3 (total time of 20 minutes plus warm-up). The second bout of exercise involved performing TABATA sessions 4 through 6 (total time of 20 minutes plus warm-up). The total exercise time was 30 minutes. Participants were asked to wait 4 – 8 hours between the 2 exercise bouts. Participants in each exercise group performed the exercise protocols on 3 non-consecutive days per week for a total of 4 weeks.

All participants were provided with Fitbit watches to keep track of their activity over the 4-week study period. The participants' activity was evaluated using average steps per day and average heart rate per day based on the Fitbit summary.

Variables to Be Evaluated

All participants had their body composition, cardiovascular fitness, and metabolic rate evaluated: 1) prior to starting the study and 2) at the conclusion of the study at 4 weeks. In addition, the participants average steps per day and average heart rate per day were documented at the end of each week. Body composition was assessed via DXA scan and included quantification of muscle mass, body fat mass, and fat-free mass. Cardiovascular fitness was assessed via a GXT and included quantification of VO_2max and time to exhaustion. Metabolic rate was assessed via evaluation of the participants' BMR and included quantification of resting VO_2 and respiratory exchange ratio (RER).

Statistical Analysis

To determine differences in the dependent variables within each of the 3 protocols (control, 1-bout and 2-bout), a paired samples t-test was performed using the pre- and post-intervention values. To determine the differences in the dependent variables between the 3 protocols, a one-way repeated measure analysis of variance (ANOVA) was performed using the difference between the pre- and post-intervention values and comparing that difference between the groups. A Bonferroni test was performed for any main effects that were found when performing the ANOVA. Dependent variables were body composition, cardiovascular fitness, and metabolic rate. Differences in the participants average steps per day and average heart rate per day were compared between the 3 protocols using a one-way repeated measure ANOVA. The criterion reference for significance was set a priori at $p < 0.05$.

RESULTS

Average Daily Heart Rate

The participants average daily heart rate during the study is reported in Table 3. There was no significant difference in the average daily heart rates between any of the groups ($p = 0.098$).

Average Exercise Heart Rate

The average exercise heart rate for the participants assigned to the 1-bout and 2-bout groups are in Table 3. The average exercise heart rates for the 2-bout group were significantly lower than the average exercise heart rates for the 1-bout group ($p = 0.0001$; ES = -6.3).

Average Steps Per Day

The participants average steps per day during the study is reported in Table 3. There was a significant difference in the average steps per day between groups ($p = 0.005$). According to a Bonferroni post hoc test, there was a significant difference in average steps per day between the control and 2-bout group ($p = 0.004$).

Body Composition

There were no significant differences between any of the groups for pre- and post-intervention weight ($p = 0.72$). There were also no significant differences between any of the groups in pre- and post-intervention body fat percent ($p = 0.06$).

Similarly, there were no significant differences between any of the groups in pre- and post-intervention fat mass (p = 0.22), fat free mass (p = 0.21), or muscle mass (p = 0.17).

There were also no significant within group differences in pre- and post-intervention body weight, body fat, muscle mass, or fat free mass in the control group, 1-bout group, or the 2-bout group. There was, however, a significant decrease in body fat percent in the 2-bout group when comparing pre- to post-intervention (p = 0.03; ES = - 0.63), but not for the 1-bout group (p =0.32; ES = -0.05). The average decrease in BF% in the 2-bout group was -1.43 ± 0.38 %.

Basal Metabolic Rate

There were no significant differences between any of the groups in pre- and post-intervention RMR (p = 0.11). There were also no significant between any of the groups in pre- and post-intervention resting VO2 (p = 0.12), or RER (p = 0.60).

Additionally, there were no significant within group differences in pre and post-intervention RMR, RER, or resting VO2 in the control group, 1-bout group, or the 2-bout group.

Cardiovascular Fitness

There were no significant differences between any of the groups for pre- and post-intervention VO2 max (p = 0.23).

In addition, there were no significant within group differences in the pre- and post-intervention measures for relative or absolute VO_2 max in the control group, 1-bout group, or the 2-bout group.

DISCUSSION

The purpose of this study was to compare the effects of Tabata, when performed as a single continuous bout or shorter accumulated bouts, on body composition, cardiovascular fitness, and basal metabolic rate. A key finding in this study was that accumulated Tabata exercise is effective at reducing body fat percent within the 2-bout group ($p = 0.03$; ES = - 0.63) by -1.43 ± 0.38 %, however, this reduction was not significantly different from the other groups. These findings are consistent with previous research (15, 20).

We did not see significant changes between any of the groups in weight ($p = 0.72$), body fat percent ($p = 0.06$), fat mass ($p = 0.22$), fat free mass ($p = 0.21$), or muscle mass ($p = 0.17$) pre- and post-intervention. One possible explanation could be the duration of the study. This study was only 4 weeks long and more time may have been needed to see meaningful changes in body composition. Chung et al. (6) reported that 12 weeks (36 total sessions) of continuous treadmill walking significantly reduced body weight and body fat in obese women whereas multiple, shorter bouts of walking did not reduce body weight or body fat. In addition, the participants of Chung et al. (6) reduced their daily caloric intake by 300 kcal. In the current study, the participants normal diet was maintained, and this may also explain in part why no significant differences in body composition were found in either of the exercise groups when compared to the control. In previous studies that have reported positive effects on body composition following accumulated exercise (20) or Tabata

(7), the duration of those studies was 10 weeks. When considering the results of the previous studies, a training period of least 10 to 12 weeks may be a more appropriate exercise volume to induce improvements in body composition.

Even though significant differences were not found between the groups at pre- and post-intervention, results did trend towards significance for reductions in body fat percentage in the 2-bout group (p = 0.06). The 2-bout group decreased in body fat percentage by an average of -1.43%, whereas the control group increased body fat percentage by .30% (ES = 2.0 vs. 2-bout) and the 1-bout group decreased body fat percentage by .27% (ES = 4.1 vs. 2-bout). Considering that the 2-bout group saw a significant decrease in body fat percent within the group (p = 0.03; ES = - 0.63), these results suggest that a longer study with a larger sample size might have resulted in a significant improvement to the participants body composition.

This study did not find significant differences between any of the groups for pre- and post-intervention VO_2 max (p = 0.23). These results agree with the findings of Murawska-Cialowicz et al. (14). Murawska-Cialowicz et al. conducted an 8-week study that compared a Tabata training group (TAB) to a non-training group (CON). The exercise groups performed Tabata exercise for 40 minutes per day, twice per week, at maximal intensity. They monitored intensity based off of the participants' heart rate max. The researchers found a significant increase in VO2 max within the TAB group (p = 0.005), but not between the TAB and CON groups (p = 0.06). They did not discuss why they didn't see a significant difference between groups. Another study, by Bermejo et al. (2), compared two different HIIT interventions on body composition. This was a 4-week study in which both exercise groups performed different types of HIIT twice per week at maximal effort. Similarly, the researchers reported that when comparing the within group pre-and post-intervention, both the cycling interval group (p = 0.011) and functional training interval group (p = 0.013) had significant increases in VO_2 max, but there was no difference when comparing between groups. The researchers speculated that since both of their groups were exercise groups and both significantly improved VO_2 max within groups, the intensity of the exercise could play a more important role than the type of HIIT being performed for cardiovascular adaptations (2).

Our results agree with the results of another study by Rodriguez-Hernandez & Wadsworth (20). In their 10-week study, Rodriguez-Hernandez & Wadsworth compared accumulated to continuous walking exercise and their effects on aerobic fitness and found no significant changes in VO_2 max between groups (p =0.913). The researchers speculated that this could have been a result of instructing their participants to exercise at a moderate intensity based off of their rate of perceived exertion (RPE). It may have been hard for untrained individuals to determine rate of perceived exertion and, consequently, RPE may not have been an accurate measure of intensity. The participants in this study were not trained and, even though they were instructed to exercise at near maximal intensity, their evaluations of how difficult the exercise was to perform may have been inaccurate. This may have potentially resulted in the exercise groups working at a lower intensity and, according to Bermejo et al. (2) and Rodriguez-Hernandez & Wadsworth (20), is one possibility for the lack of significant changes in VO2 max. This theory is supported by the significant difference reported in our study in exercise heart rates between the 1-bout and 2-bout groups (p = 0.0001). Additionally, the exercise sessions for the exercise groups were not supervised, thus, there was no way for us to verify the intensity of the exercise being performed by the participants.

This study did not find significant differences between any of the groups in pre- and post-intervention RMR (p = 0.11), resting VO2 (p = 0.12), or RER (p = 0.60). Schubert et al (22) reported that 4 weeks of Wingate-based spring interval training (SIT) significantly increased resting metabolic rate with no change in RER in both young men and women. Pearson et al. (17) reported that a single bout of Tabata significantly increased fat oxidation (lowered RER) the following morning when compared to control in the fasted state (P = 0.010), and at 1-hour (P = 0.005), 2 hours (P = 0.013), and 3 hours postprandial (P = 0.017). Based on the results of both Pearson et al. (17) and Schubert et al. (22) it is plausible to suggest that Tabata training or other forms of HIIT can increase basal metabolic rate and alter substrate oxidation. It has been suggested that skeletal muscle contributes the most towards resting energy expenditure and, therefore increases in muscle mass may lead to the most significant increases in RMR (4). As previously stated, the current study did not see significant changes between any of the groups in pre- and post-intervention muscle mass (p = 0.17). There was a non-significant (p = .06) increase in muscle mass of 1.7% in the 2-bout group but this did not translate into a higher BMR. A longer period of Tabata training (1-or 2-bout) that included more participants may have resulted in a significant increase in muscle mass, and thus, a significant increase in BMR.

The average exercise heart rates between the 1-bout and 2-bout groups were significantly different (p = 0.0001; ES = -6.3). The difference in exercise heart rates between the 1-bout group and the 2-bout group may have been due to a longer exercise bout in the continuous protocol. Exercising for 30 minutes continuously possibly facilitated a higher heart rate response than 15 minutes of exercise did. This also shows that even though both exercise groups were instructed to perform the exercise at the same intensity, the participants may not have adhered to the instructions that well. As previously stated, this could also be a result of untrained individuals having difficulty accurately estimating the intensity of exercise based off self-perception (20).

Limitations

To the author's knowledge, this is the first study to investigate the effects of accumulated Tabata exercise on body composition, cardiovascular fitness, and resting metabolic rate. Nonetheless, this study had several limitations. First, the sample size was small (n = 9). There were only 3 participants in each group. Second, although the participants were instructed to maintain their normal diet for the duration of the study, we did not control for diet. Third, we did not blind the display of the Fitbit watch to the participants. This could potentially be a threat to the internal validity of the study. Some research has shown that simply having a display of daily activity could potentially be a source of motivation for participants to be more active than usual, specifically, in physically inactive populations (21). Finally, the exercise bouts were not supervised. The participants in the exercise groups were instructed to perform their exercise at home on their own time. This could potentially be a threat to the internal validity of the study.

Conclusion

In conclusion, both continuous and accumulated Tabata exercise seem to have no effect on body composition, cardiovascular fitness, or resting metabolic rate. These findings contradict past research done on both accumulated exercise and Tabata exercise. However, Tabata exercise is still potentially valuable exercise mode as it may be more convenient type of exercise. Accumulating Tabata exercise throughout the day could make reaching minimum recommendations for exercise more achievable for people with busy schedules. Future studies should utilize larger sample sizes over a longer period. They should also blind the display of the fitness tracker used to measure daily activity and heart rates, control for diet, and supervise each prescribed exercise bout.

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Table 1. The Bruce Protocol.

Stage	Duration (min)	Speed (MPH)	Grade (%)
1	3	1.7	10
2	3	2.5	12
3	3	3.4	14
4	3	4.2	16
5	3	5	18
6	3	5.5	20
7	3	6	22

Table 2. Participant Anthropometrics

Variable	Pre-Treatment			Post-Treatment		
	C (n = 3)	1-bout (n = 3)	2-bout (n = 3)	C (n = 3)	1-bout (n = 3)	2-bout (n = 3)
Age (Years)	23 ± 1.7	23 ± 1.7	30.7 ± 15.9	Assumed to be the same as pre		
Height (cm)	168.9 ± 4.6	175 ± 8.7	169 ± 5.2	Assumed to be the same as pre		
Weight (lbs)	178 ± 88.5	182.2 ± 86.3	170.4 ± 29.2	178.4 ± 85.7	182.5 ± 88.7	169.3 ± 30.9
Body Fat (%)	34.5 ± 12.1	31.8 ± 6.7	41.4 ± 2.8	34.8 ± 11.1	31.5 ± 7	40 ± 2.9
FFM (lbs)	111.3 ± 36	122.8 ± 44.9	101.6 ± 15.2	111.7 ± 35.5	123.1 ± 45.9	103.2 ± 15.9
FM (lbs)	66.6 ± 54.8	59.4 ± 41.5	68.8 ± 14.8	66.7 ± 52.3	59.4 ± 42.9	66.2 ± 15.6
MM (lbs)	105.5 ± 34.8	116.2 ± 42.9	96.4 ± 14.6	105.9 ± 34.3	116.5 ± 43.9	98.1 ± 15.2

note . All values represent mean ± SD. FFM = fat free mass. MM = muscle mass. FM = fat mass.

Table 3. Average Steps Per Day and Average Heart Rates

	C (n = 3)			1-bout (n = 3)			2-bout (n = 3)		
	Avg. Steps	Avg. HR	Avg. Ex HR	Avg. Steps	Avg. HR	Avg. Ex HR	Avg. Steps	Avg. HR	Avg. Ex HR
Week 1	3245 ± 698.5	64.3 ± 3.2	N/A	6553 ± 2435.3	70.5 ± 2.1	156.6 ± 31.2	7632.5 ± 1919.8	66.9 ± 4.4	136.8 ± 9.4
Week 2	3955 ± 2010.8	65.7 ± 3.2	N/A	6261 ± 230.5	69 ± 2.8	158.4 ± 32.1	9616 ± 3718	67.5 ± 3.5	136.2 ± 6.7
Week 3	4630.3 ± 2435.6	66 ± 1	N/A	5192 ± 2765.3	69.7 ± 2.8	150.1 ± 29.9	5409.3 ± 4387.9	73.7 ± 9.1	134 ± 9.6
Week 4	4375.5 ± 1608.7	69 ± 1.4	N/A	6816.7 ± 2828.1	73 ± 4.4	154 ± 20.4	7738 ± 2186.4	75.9 ± 6.9	130.4 ± 19.8

note . All values represent mean ± SD.

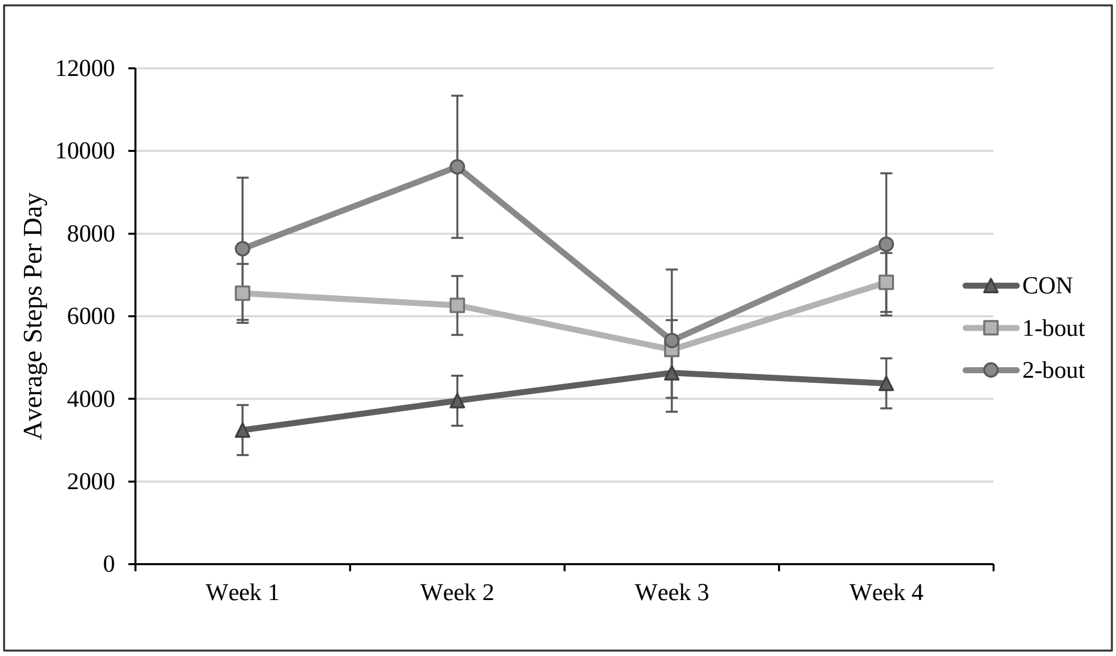

Figure 1. Average steps per day over the 4-week period.

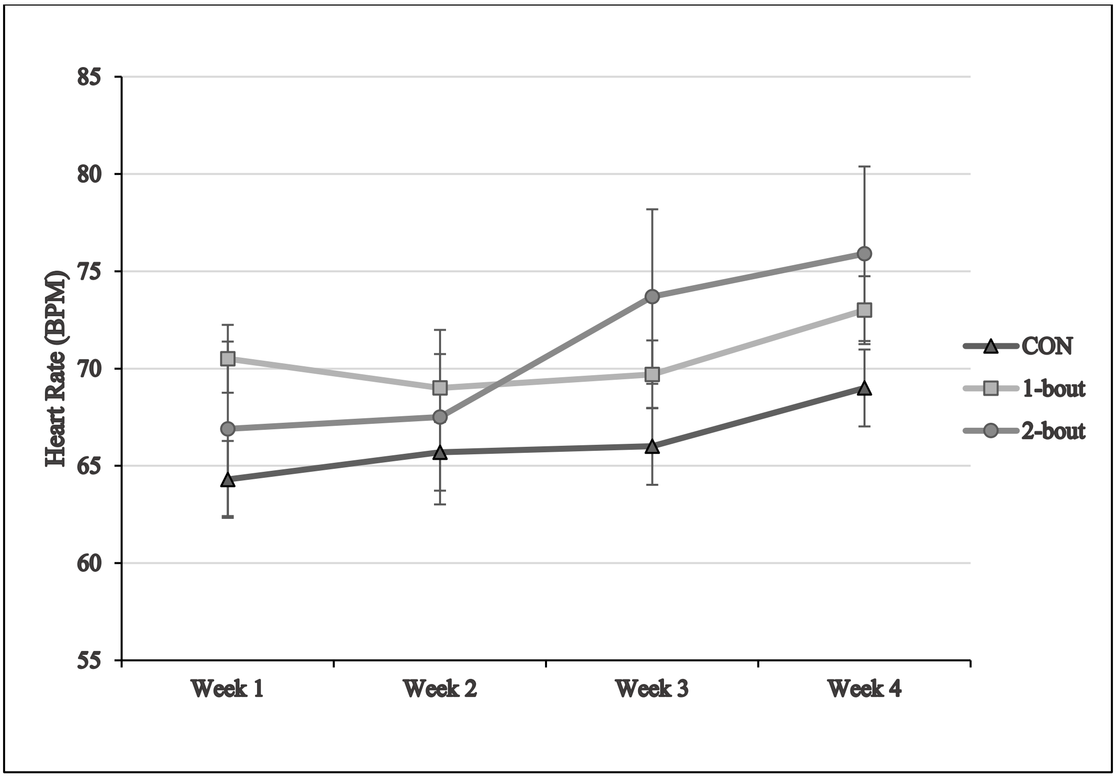

Figure 2. Average resting heart rates over the 4-week period.

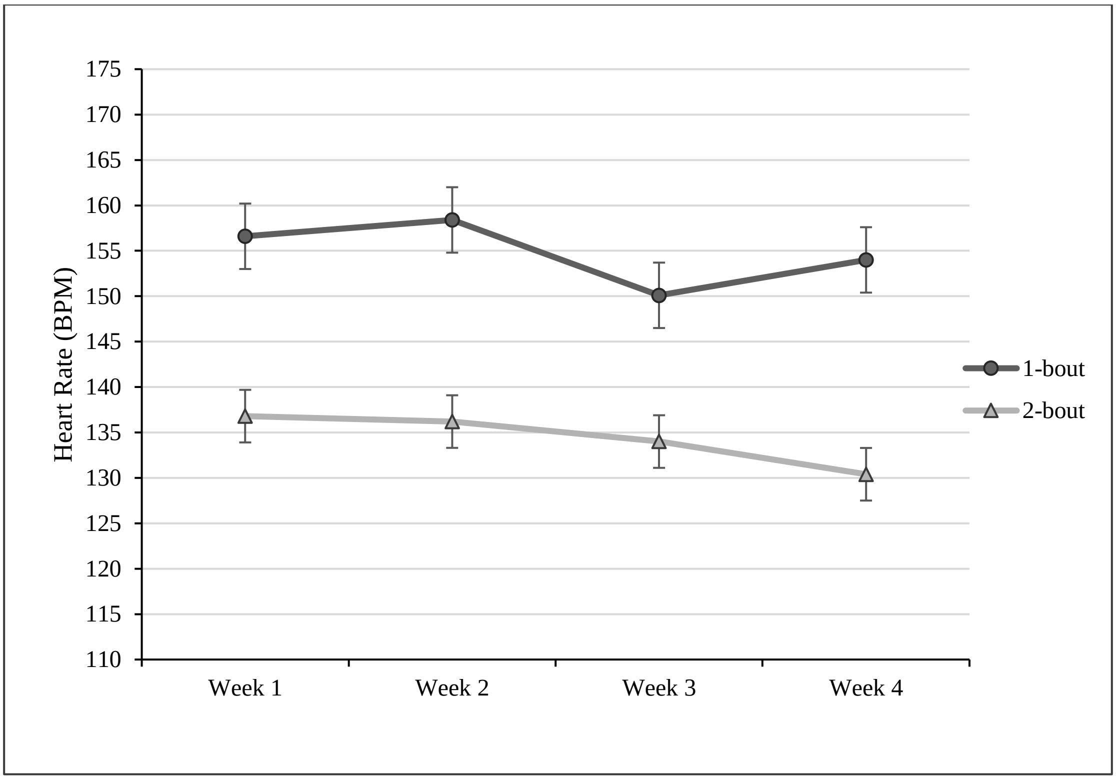

Figure 3. Average exercise heart rates over the 4-week period.

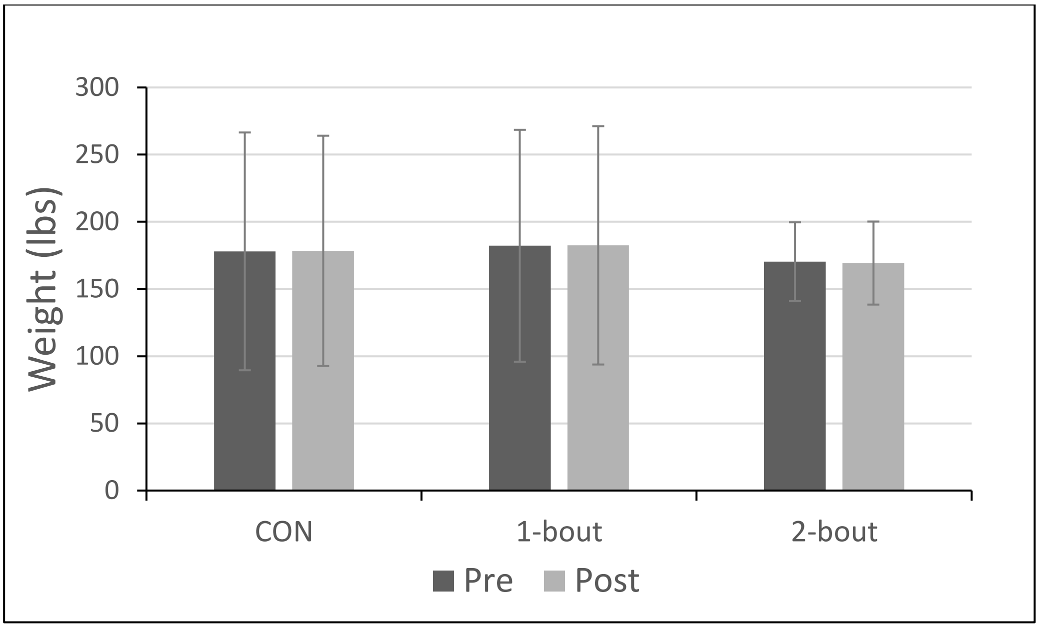

Figure 4. Pre- and post-intervention body weight.

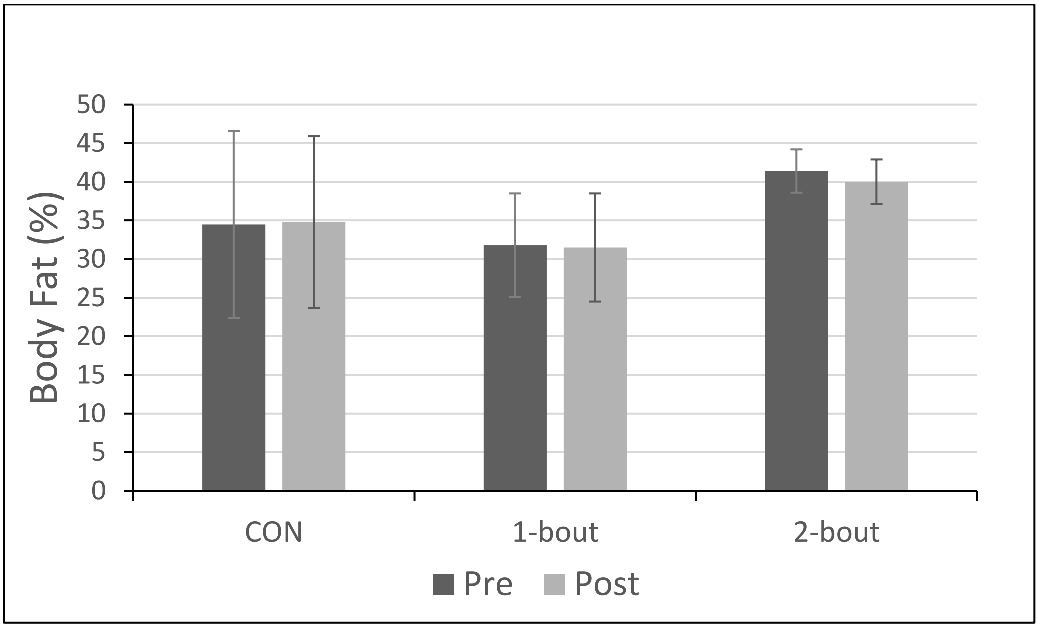

Figure 5. Pre- and post-intervention body fat percent.

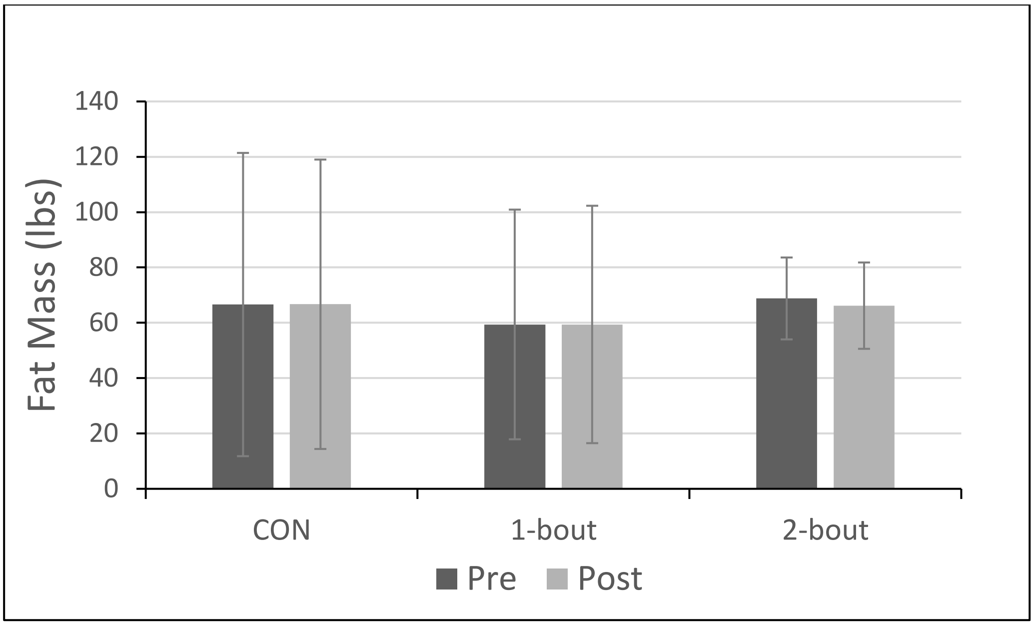

Figure 6. Pre- and post-intervention fat mass.

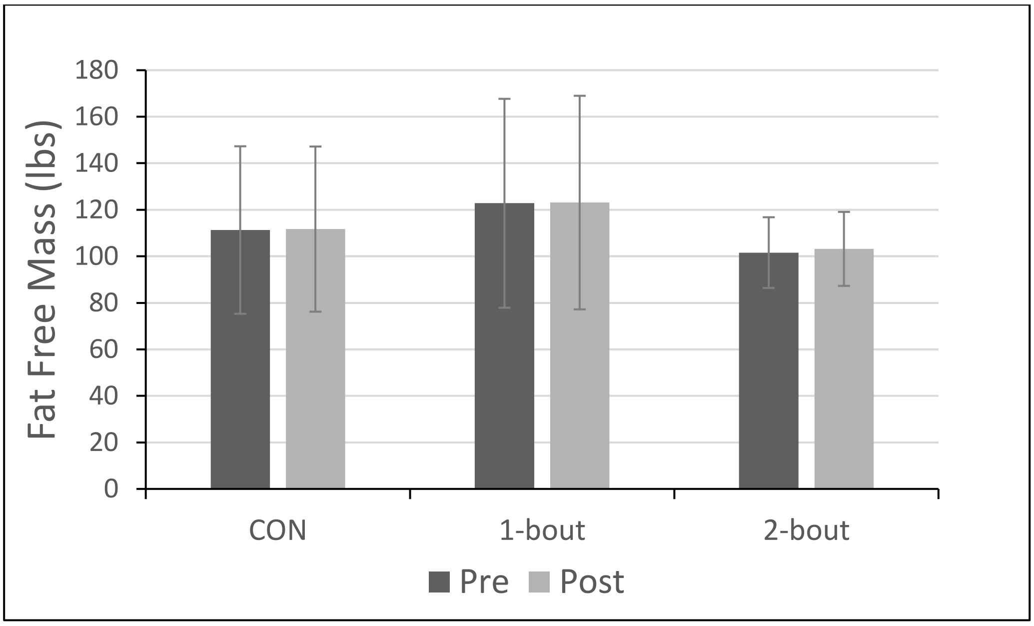

Figure 7. Pre- and post-intervention fat free mass.

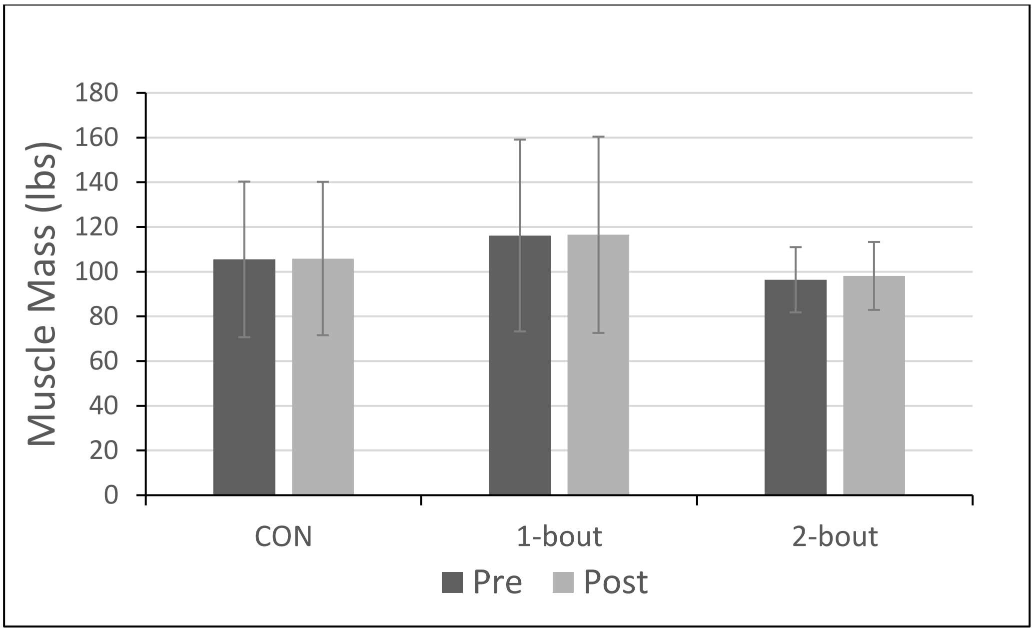

Figure 8. Pre- and post-intervention muscle mass.

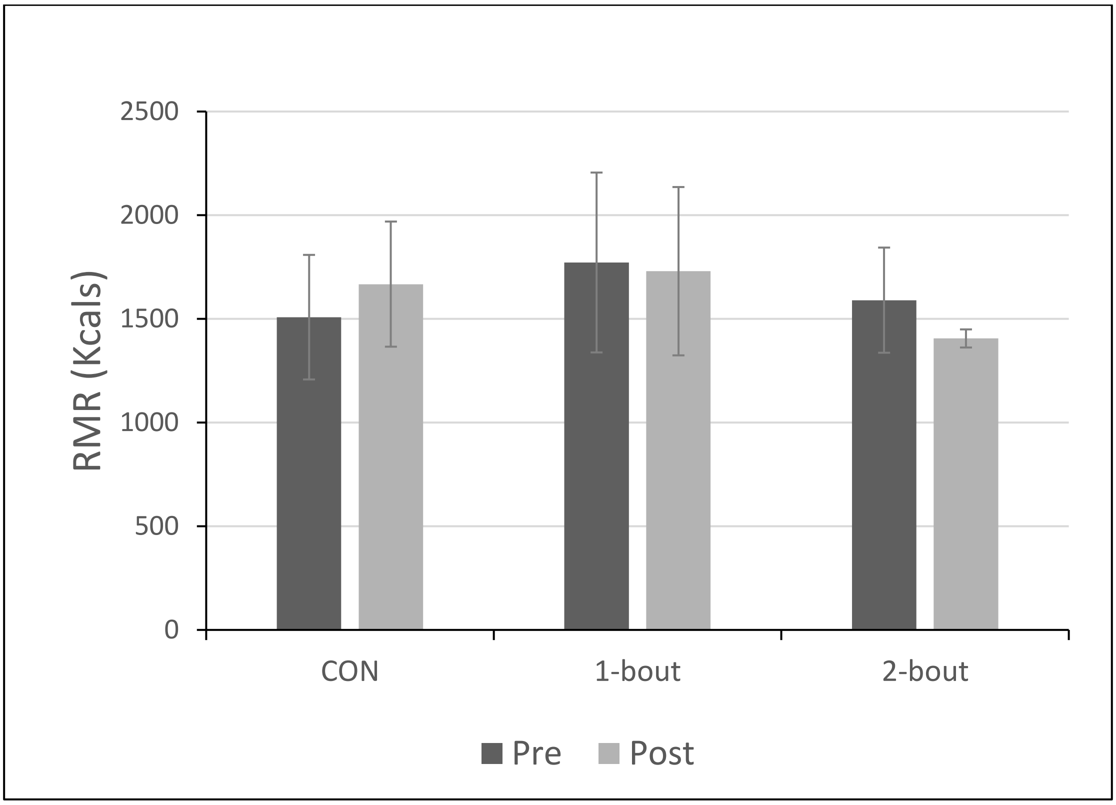

Figure 9. Pre- and post-intervention resting metabolic rate.

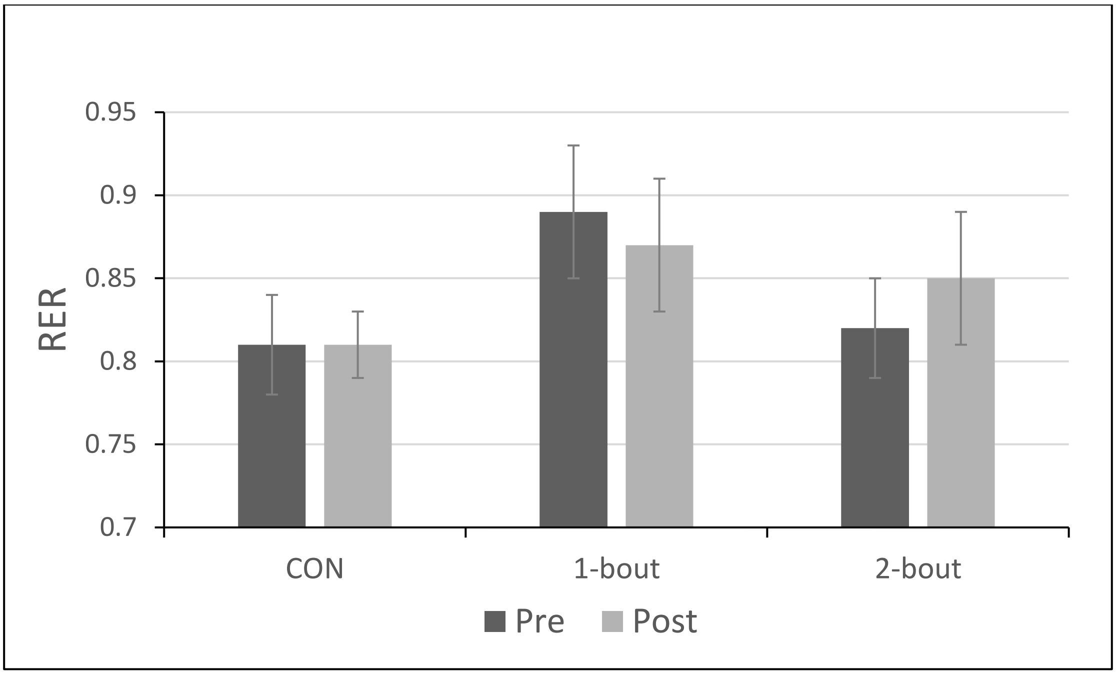

Figure 10. Pre- and post-intervention respiratory exchange ratio.

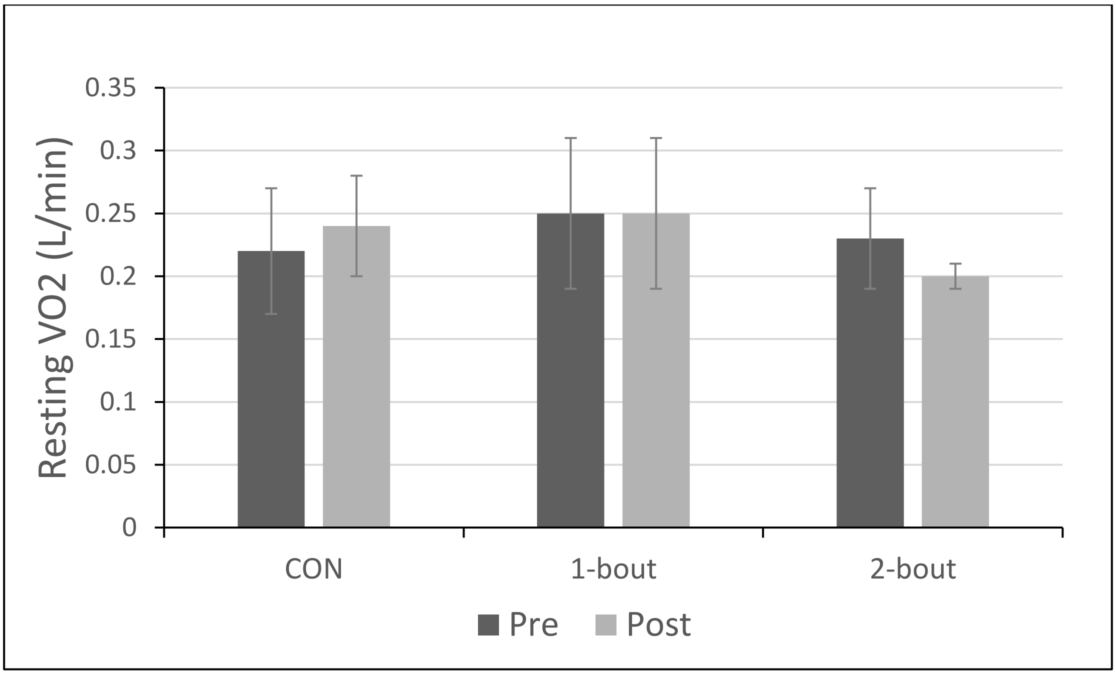

Figure 11. Pre- and post-intervention resting VO2.

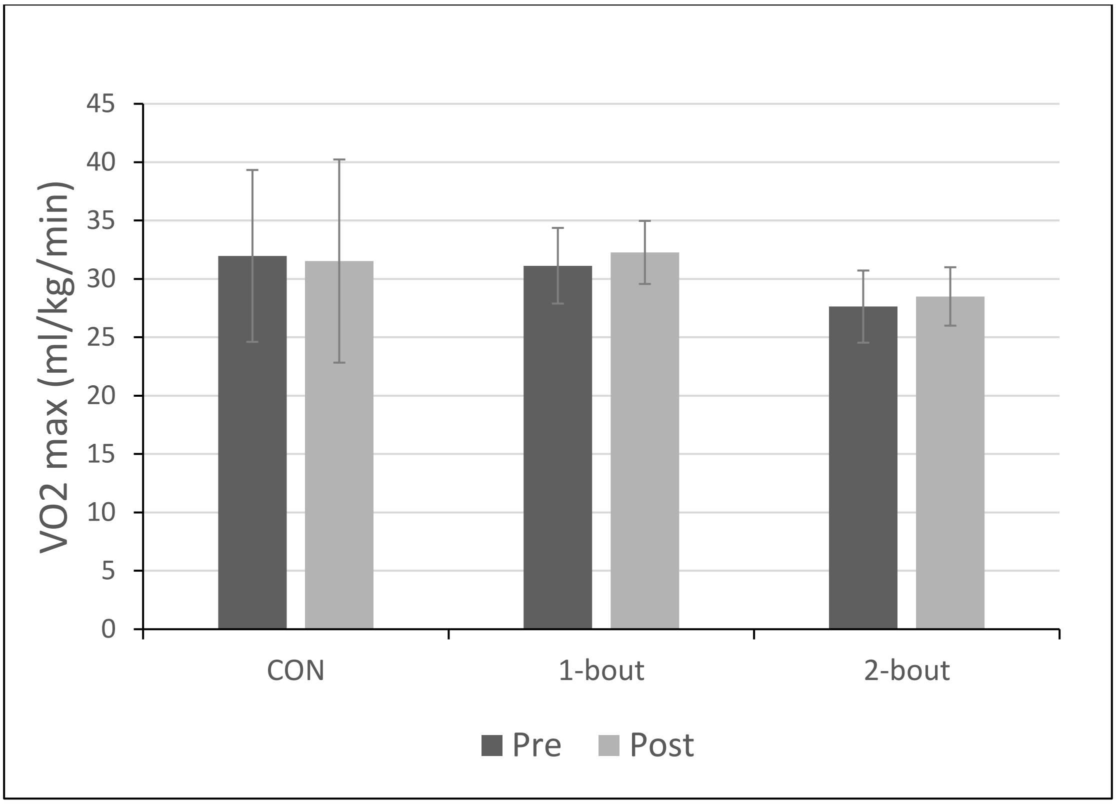

Figure 12. Pre- and post-intervention VO2 max.

Vita

Alexander Alvara, a graduate of New Caney High School, enrolled at Stephen F. Austin State University in Nacogdoches, Texas in the fall of 2016. He received a Bachelor of Science in Kinesiology with an emphasis in fitness and human performance in May 2019. The following semester, Alexander enrolled in the Graduate School of Stephen F. Austin State University where he was hired as a Graduate Assistant. As a Graduate Assistant, he was the instructor of record for multiple lab courses and a lecture course in the Kinesiology and Health Science Department and assisted with several research projects.

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Style manual designation: *International Journal of Exercise Science.*

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