# CALORIC EXPENDITURE DURING ONE EXERCISE SESSION FOLLOWING ACSM AND CROSSFIT® GUIDELINES

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# ABSTRACT

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**Purpose.** This study sought to compare energy expenditure, recovery $VO_2$ and peak heart rates and $VO_2$'s achieved across 45 min of exercise and 15 min of recovery following both CrossFit® and ACSM guidelines. **Methods.** Thirty physically active participants performed a workout following both CrossFit® and ACSM guidelines. During each workout the participants wore a K4b2 Cosmed unit to measure energy expenditure, $VO_2$ and heart rate. **Results.** Energy expenditure (468 ± 116 vs. 431 ± 96 kcal), peak heart rate (189 ± 8 vs. 172 ± 8 bpm), peak $VO_2$ (3.22 ± 0.73 vs. 2.81 ± 0.63 L/min) and average 15 min recovery $VO_2$ (0.89 ± 0.24 vs. 0.78 ± 0.18 L/min) were significantly greater in the CrossFit® workout ($p < .05$). **Conclusion.** CrossFit® can be an effective exercise program for expending calories, although the high intensity may be unsafe for individuals with health conditions.

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# CHAPTER I

# INTRODUCTION

For decades the pursuit of physical fitness has been one of the defining pastimes of society (US Department of Labor, Bureau of Labor Statistics and US Department of Commerce, US Census Bureau, 2007). With discoveries in the importance and benefits of physical activity, a multitude of fitness programs have been designed, involving weightlifting, running, cycling, stepping, dancing and many others (U.S. Department of Health and Human Services, 1996). For the past 59 years, an organization that has been a leading authority in this pursuit of fitness is the American College of Sport Medicine. The American College of Sport Medicine, or ACSM, is the largest sports medicine and exercise science organization in the world. They include over 45,000 members and certified professionals around the globe (ACSM, 2013). With their team of physical activity experts, the ACSM has defined the exercise prescriptions to be performed in order to become fit. These guidelines include specific details on how to specifically prescribe exercise, such as exercise mode (type), frequency, structure, duration and intensity (American College of Sports Medicine, 2010).

Over the past 13 years, a new form of exercise in the pursuit of fitness has been growing in popularity. This new exercise program is called CrossFit. CrossFit® was designed by a personal trainer out of California named Greg Glassman. Its original intent was to be a training program for emergency personnel and first responders (military, firemen, police officers, paramedics) who never knew what physical challenges awaited them in the field. Glassman (2002) argues that performing no single mode of exercise adequately prepares one for the challenges presented in life, and therefore single-event athletes cannot be defined as "fit". A "fit" individual, according to CrossFit® standards, is someone who is not excellent in any one field of fitness, but who is "competent" in each one. Subsequently, CrossFit® is a training program that involves elements of almost all modes of exercise. It is a combination of various forms of powerlifting, Olympic lifting, strongman events, gymnastics, plyometrics, running, rowing, and more. The exercises are combined in a relatively random fashion with a relatively random number of repetitions, in order to simulate the random and unexpected challenges that emergency responders might encounter in the field (Glassman, 2002). It is an approach similar to cross training, which explains why the name is similar to CrossFit®. On top of the variability of exercises, CrossFit® also adds an element of time. The workouts must be completed as fast as possible. This element of time also adds an element of competition. A handful or dozens of people will perform the workout at the same time and, under the guidance of a coach, will compete with one another for the best score. This element of competition, according to Glassman (2002), has led to people exercising harder than they ever have before. This class structure encourages people to push themselves harder, but it also adds a sense of camaraderie (Glassman, 2002). The sense of community built around this high intensity, and sometimes painful, workout program has become a worldwide phenomenon. CrossFit® has over 5,000 affiliates worldwide, and that statistic is nearly doubling every year (Tabata Times, 2013). It has become so popular that for the past 2 years ESPN has featured the Crossfit Games (the CrossFit® world championships) in its summer lineup. CrossFit® claims to be “empirically driven” but very little research has been performed on it since it began (Crossfit, 2013). One example of recent research is that of Smith and colleagues (2013), who determined that a CrossFit®-based training program improved $VO_{2max}$ and body composition. An example of what a CrossFit® workout might look like is depicted in Table 1. This is also the same workout used in this study.

Table 1

*CrossFit® Sample Workout*

A. Back Squat 5x5 @ 75% 1RM
B. As Many Rounds as Possible in 15 minutes:

   Run 324 m

   10 Up-and-Downs

   15 Kettlebell Swings

The health status of people in modern society is less than ideal. More than 66% of adults are overweight or obese, and the overall cost associated with treating weight-related diseases exceeds $117 billion annually (Stein & Colditz, 2004). Even worse than the financial cost, 1.9 million deaths and 19 million disability-adjusted life-year losses are associated with overweight and obesity annually (World Health Organization, 2003). Although the solution is undoubtedly multi-faceted, one of the main answers is that people need to perform more exercise (American College of Sports Medicine, 2001; U.S. Department of Health and Human Services, 1996). There is ever accumulating evidence of an inverse relationship between physical activity and chronic diseases such as cardiovascular disease, hypertension, stroke, osteoporosis, type 2 diabetes, obesity, colon cancer, breast cancer, and even anxiety and depression (Feskanish, Willet & Colditz, 2002; Haskell et al., 2007; Kesaniemi et al., 2001; Leitzmann et al., 1999). It does not even take substantial effort to achieve these benefits, and according to the National Heart, Lung, and Blood Institute (NHLBI), losing only 3-5% bodyweight can result in significant reductions in chronic disease, anxiety and depression (1998). These health risks only become exacerbated with time, for as individuals age, the risk of cardiovascular disease increases. However, physically active adults can cut their risk by 25-50% (Powell et al., 1987; Williams, 2001). Indeed, some data suggests that the prevalence of sedentary behavior has begun to decline, but physical inactivity is still too high. In a year-long survey conducted by the Centers for Disease Control and Prevention

(2005), only 49.1% of U.S. adults met the recommendation of 30 min of exercise a day on most days of the week. It was discovered that the most popular physical activity in the U.S. is walking, but fewer than 7% of walkers perform enough work to meet the ACSM minimum guidelines (Rafferty et al., 2002; Simpson et al., 2003). In the American Time Use Survey, which surveyed 45,246 individuals age 18 and up between 2003 and 2005, it was found that 25% of adults participated in any sport, exercise, or recreational activity on a random given day, and 60.9% of adults had participated in leisure time activity in the past 30 days. The most common activities reported were walking, gardening and yard work. Overall, the prevalence and duration of physical activity was low (Centers for Disease Control and Prevention, 2007; US Department of Labor, Bureau of Labor Statistics and US Department of Commerce, US Census Bureau, 2007). Overall, only 32% of US adults and 66% of children and adolescents engage in regular physical activity (Barnes & Schoenborn, 2003). Programs such as Healthy People 2000 and Healthy People 2010 were implemented to help combat this epidemic. Their purposes were to spend the next decades pushing for reductions in the prevalence of dozens of health risks, including cancer, kidney disease, and physical activity and fitness. Unfortunately, both programs were met with minimal success in reducing the prevalence of obesity (U.S. Department of Health and Human Services, 1998).

## Statement of the Problem

CrossFit® is a rapidly growing exercise program that many choose to adopt as their sole pursuit of health and fitness. Major organizations such as the ACSM are unable to provide clear recommendations or condemnations for the program because it has not yet been the focus of any research (Bergeron et al., 2011). The question remains as to whether it meets the exercise prescription standards set by popular health and fitness organizations such as the ACSM. An important factor in those prescriptions is how many calories the individual burns, particularly because of the current obesity problem (Stein & Colditz, 2004). It is important to consider not only the calories burned during exercise, but also the elevated metabolism following exercise, deemed excess postexercise oxygen consumption (EPOC; Binzen, Swan, & Manore, 2001). It is also important to consider the intensity of exercise, such as the maximum $VO_2$ and heart rate achieved, because of the risks associated with very high levels when performed by individuals with risk for or who currently have cardiac disease (American College of Sports Medicine, 2010). The purpose of this study is to compare the caloric expenditure, short-term EPOC, and maximum heart rate and $VO_2$'s achieved in trained, healthy young males and females following both ACSM and CrossFit® exercise prescriptions. Exercise prescriptions for both the ACSM and CrossFit® will be detailed in Chapter II. Individuals will wear a portable metabolic device called the K4b2 Cosmed and a Polar Heart Rate Monitor and then perform a 45 min exercise session and 15 min recovery session under both ACSM and CrossFit® guidelines. The Cosmed will measure the individual's energy expenditure, $VO_2$ and heart rate during each session. The data will be saved to a computer program for statistical comparisons following the study. For the purposes of this study, the exercise following ACSM prescriptions will be referred to as "traditional" exercise.

## Hypotheses

The following hypotheses are tested in this study:

$H_0$ – There will be no statistically significant difference in calories expended across the 1 hr sessions of performing traditional and CrossFit® exercise prescriptions.

$H_0$ – There will be no statistically significant difference in average $VO_2$ during the 15 min recovery period between traditional and CrossFit® exercise prescriptions.

$H_0$ – The peak $VO_2$ and heart rate achieved will not be different between the CrossFit® prescribed workout and the traditional prescribed workout.

## Definition of Terms

Body Mass Index (BMI) – Relation of body mass to height. The calculation is body weight (kilograms) divided by height$^2$ (meters; Brooks, Fahey, & Baldwin, 2005).

Circuit Training – Exercise in which an individual performs different exercises in a rotation, such as combining different exercises in order to elicit a cardiorespiratory response.

Cross Training – Refers to an individual training in multiple sports or activities, such as both running and weightlifting.

Excess Post-Exercise Oxygen Consumption (EPOC) – Anaerobic metabolism during exercise results in an in increased need for $O_2$ following the exercise session. As a result, $VO_2$ remains elevated following exercise and thus, energy expenditure remains elevated above resting levels (Brooks, Fahey, & Baldwin, 2005).

Fitness – A general term referring to an individual's ability to perform work. There is disagreement between the ACSM and CrossFit® over its definition. ACSM defines fitness as attributes or characteristics people have that relate to their ability to perform physical activity, where physical activity is any bodily movement that requires skeletal muscle contraction and a substantial increase in resting energy expenditure (American College of Sports Medicine, 2010). In his article *What Is Fitness?*, Greg Glassman (2002) defines it as having an increased work capacity across broad time and modal domains. Competing views on the definition of fitness may be what leads to different exercise prescriptions between the ACSM and CrossFit®.

Gymnastics – If defined by CrossFit®, gymnastics involves all activities like climbing, yoga, calisthenics and dance where the aim is body control (Glassman, 2002).

Healthy – For the purposes of this study, a healthy individual will be defined as someone who is in the low risk category for ACSM's risk stratification for atherosclerotic cardiovascular disease (American College of Sports Medicine, 2010). Also, the individual must possess no injuries or disabilities that might impair them from performing the exercise.

Kilocalorie (kcal) – The calorie is a basic unit of heat measurement. It refers to the heat required to raise the temperature of 1 g of water by 1° C (Brooks, Fahey, & Baldwin, 2005). The kilocalorie is the more commonly used unit, which equals 1000 calories.

Obesity – Defined as having a BMI of 30 $kg/m^2$ or more (CDC, 2012).

Olympic Lifting – A competitive sport which includes the two basic barbell power exercises: Clean and Jerk, and Snatch.

One Repetition Maximum (1RM) – The most weight an individual can successfully lift of an exercise for 1 repetition

Oxygen Consumption ($VO_2$) – The rate at which an individual consumes $O_2$. The maximum rate at which an individual can use oxygen is called their $VO_{2max}$ (Brooks, Fahey, & Baldwin, 2005).

Plyometrics – Defined by the ACSM as exercises that elicit both speed and strength to produce power, or simply “jump training” (ACSM).

Powerlifting – A competitive sport which includes the three basic barbell strength exercises:  Squat, Press and Deadlift.

Repetition (Rep) – A single exercise movement performed to completion

Set – A group of repetitions performed without rest

Strongman events – A competitive sport which includes the plethora of activities performed in strongman competitions, mostly involving the pushing/pulling/holding/throwing/carrying of heavy objects.

Trained – For the purposes of this study, a trained individual will be defined as someone who has exercised at least 3 days per week, 1 hr per session, for the past 6 months.

Wingate Endurance Test – A test of anaerobic endurance involving an all-out effort on a cycle ergometer for 30 s

Young – For the purposes of this study, young adults will be defined as being between 18-44 years of age.  Once an individual turns 45, his or her risk for a sudden cardiac event increases (American College of Sports Medicine, 2010).

## Assumptions

It is assumed the following conditions exist for this study:

- The participants know how to perform all the exercises
- The participants will work as hard as they are able
- The participants will follow the same preexercise sleep pattern and food/fluid consumption prior to the second session

## Limitations

The following shortcomings may affect the outcome of this study:

- Only participants defined as "young" and "trained" will be used
- One workout is not representative of an entire mode of exercise
- Unable to compare long-term EPOCs following the 15 min recovery period

## Significance of the Study

CrossFit® continues to grow and is becoming the program of choice for many people around the world seeking a healthy lifestyle (Tabata Times, 2013). The validity of CrossFit® as a training program has not been properly tested and documented, so it will be compared to the standard set by the ACSM. It is most important to document the energy expenditure during a CrossFit® session because of the current obesity epidemic (Stein & Colditz, 2004). Heart rate and $VO_2$ must also be measured so that the safety of a CrossFit® program can be determined for individuals with signs/symptoms of cardiovascular or pulmonary disease. The heart rate and $VO_2$ measures found will also identify if this is a valid exercise program for healthy individuals who want to increase their cardiorespiratory fitness. This study will also be an important opportunity to learn how different combinations of repetitions and rest intervals influence $VO_2$, heart rate and energy expenditure. It will also provide an opportunity to examine the $VO_2$, energy expenditure, and short-term EPOC following a conditioning workout at a self-paced intensity (CrossFit®) and a conditioning workout at a prescribed intensity (ACSM).

# CHAPTER II

# REVIEW OF THE LITERATURE

## CrossFit®

The following section introduces the ideas that conceived CrossFit® and are not necessarily the views of the author. The aim of CrossFit® is to forge a broad, general and inclusive fitness (Crossfit, 2013). Greg Glassman (2002) defined fitness as an increased work capacity across broad time and modal domains, and CrossFit® optimizes fitness through constantly varied functional movements performed at relatively high intensity. 'Capacity' refers to the ability to perform work, measured in physical terms of force, distance and time. Work is defined as $Force\ x\ Distance$, and power is defined as $\frac{Force\ x\ Distance}{Time}$. Life is unpredictable, so individuals must not specialize in any 'mode' or 'time domain' of exercise. The term 'relatively high intensity' refers to the maximum tolerances of the individual, both physical and psychological. The CrossFit® methodology proposes that the ultimate fitness regimen comes from combining all possible sport and physical tasks in order to prepare an individual for any imaginable situation. One example Glassman provides is that if someone has each of the capacities of a novice 800-meter track athlete, gymnast and weightlifter, then he or she is more fit than any world class track athlete, gymnast or weightlifter.  Greg Glassman attempted to shorten his theory into one hundred words:  "Eat meat and vegetables, nuts and seeds, some fruit, little starch and no sugar.  Keep intake to levels that will support exercise but not body fat.  Practice and train major lifts:  Deadlift, clean, squat, presses, clean & jerk, and snatch.  Similarly, master the basics of gymnastics:  pull-ups, dips, rope climb, push-ups, sit-ups, presses to handstand, pirouettes, flips, splits, and holds.  Bike, run, swim, row, etc, hard and fast.  Five or six days per week mix these elements in as many combinations and patterns as creativity will allow.  Routine is the enemy.  Keep workouts short and intense.  Regularly learn and play new sports" (2002).

CrossFit® aims to harness the natural camaraderie, competition and fun of sport and competition by training in group environments under pressure of time so that individuals will exercise at their maximum possible intensity (Crossfit, 2013).  Due to the nature of this study, participants will not exercise in a class setting.  CrossFit® has brought forth a new sport deemed "the sport of fitness", and their world championship event called the Crossfit Games is even featured in the ESPN summer lineup.  Another important concept in their exercise environment is "scalability".  On a given day, everyone should perform the same workout, but with the exercises scaled to their skill and fitness level (Crossfit, 2013).  For the purposes of this study, however, individuals will not be training in a group environment.

The business of CrossFit® provides training seminars all over the world with certifications accredited by the American National Standards Institute (ANSI). ANSI was founded in 1918 and helps businesses to create standards and assessment systems in order to promote professionalism and safeguard their integrity (ANSI, 2013). CrossFit® publishes several websites which offer free workouts and support for the public, as well as their own journal. There are over 5,500 affiliated gyms and 35,000 accredited trainers around the world, with dozens more affiliates and hundreds more trainers appearing every month (Crossfit, 2013). The CrossFit® Level 1 Trainer Course, or basic CrossFit® certification, offers teaching and coaching to certify individuals as Level 1 CrossFit® coaches.

CrossFit® has three fitness standards. The first comes from becoming competent in the 10 general physical skills (listed below). The standards are different than the ones proposed by the ACSM. Their second standard is that CrossFit® is about performing well at any and every possible physical task. The third standard involves improving each of the body's three metabolic pathways: Phosphagen, Glycolytic and Oxidative (Glassman, 2002). The standards of fitness according to CrossFit® are listed in Table 2.

Table 2

*CrossFit® Fitness Standards*

| **Component** | **Definition** |
|---|---|
| Cardiovascular Endurance | The ability of body systems to gather, process and deliver oxygen |
| Stamina | The ability of body systems to process, deliver, store, and utilize energy |
| Strength | The ability of a muscular unit, or combination of muscular units, to apply force |
| Flexibility | the ability to maximize the range of motion at a given joint |
| Power | The ability of a muscular unit, or combination of muscular units, to apply maximum force in minimum time |
| Speed | The ability to minimize the time cycle of a repeated movement |
| Coordination | The ability to combine several distinct movement patterns into a singular distinctive movement |
| Agility | The ability to minimize transition time from one movement pattern to another |
| Balance | The ability to control the placement of the bodies center of gravity in relation to its support base |
| Accuracy | The ability to control movement in a given direction or at a given intensity |

## American College of Sports Medicine

The first meeting of what was then called the "Federation of Sports Medicine" occurred in New York City on April 22, 1954 as a stem of the American Association for Health, Physical Education and Recreation (AAHPER). It wasn't until the following year that the American College of Sports Medicine was originally founded. It began with 11 individuals, all with degrees in physical education or medicine. Their specialties were primarily in exercise physiology and cardiology. In 1961, Grover W. Mueller, M.S., became the first executive secretary and established a permanent office in Philadelphia. In 1969 they published their first issue of the *Medicine and Science in Sports*. Later on in 1979, they also took on the publication of *Exercise and Sport Sciences Reviews* (ACSM, 2013). The ACSM is a now one of the most recognized authorities in the field of Kinesiology. Its contributions range from those in sports medicine and exercise science, offering position stands, opinion statements, certifications, journals, books, newsletters, lecture tours, conferences, media education, clinical programs, and annual meetings (ACSM, 2013).

The ACSM identified 11 different categories to encompass the meaning of physical fitness. These are further divided into two subcategories: health-related physical fitness components and skill-related physical fitness components (American College of Sports Medicine, 2010). These are listed in Table 3.

Table 3

*ACSM Fitness Standards*

| Component | Definition |
|---|---|
| | **Health-Related Components** |
| Cardiovascular Endurance | The ability of the circulatory and respiratory system to supply oxygen during sustained physical activity |
| Body Composition | The relative amounts of muscle, fat, bone, and other vital parts of the body |
| Muscular Strength | The ability of muscle to exert force |
| Muscular Endurance | The ability of muscle to continue to perform without fatigue |
| Flexibility | The range of motion available at a joint |
| | **Skill-Related Components** |
| Agility | The ability to change the position of the body in space with speed and accuracy |
| Coordination | The ability to use the senses, such as sight and hearing, together with body parts in performing tasks smoothly and accurately |
| Balance | The maintenance of equilibrium while stationary or moving |
| Power | The ability or rate at which one can perform work |
| Reaction Time | The time elapsed between stimulation and the beginning of the reaction to it |
| Speed | The ability to perform a movement within a short period of time |

## CrossFit® in the Literature

As CrossFit® has begun to expand, the ACSM has taken notice. At their 2012 annual health and fitness summit, ACSM held a session discussing the CrossFit® program. The session was largely informational and neither confirmed nor denied the programs effectiveness. Also, an executive summary was put together by both the ACSM and CHAMP (Consortium for Health and Military Performance) over what was called "extreme conditioning" programs such as CrossFit®, P90X, Insanity and Gym Jones (Bergeron et al, 2011). They recognized that such programs do in fact address the intense physical demands required by warfighters, but as with any high intensity program, there's a higher risk for overtraining and injury. Their overall view was positive but they neither condoned nor condemned the program. They suggested that more research is needed in order to supply a safe, reliable and efficient program to meet the needs of the military. One limit to the summary was that it was a statement for the military and didn't address the needs of the general public. Other than this statement, no documented research has been performed on CrossFit®.

## Exercise Recommendations

The U.S. Surgeon General's Report (1996) states general guidelines for exercise prescription, stating that health benefits can be obtained by exercising at a moderate intensity on most, if not all, days of the week. The report also states that greater health benefits can be obtained by exercising for a longer duration or at a more vigorous intensity (U.S. Surgeon General's Report, 1996). The benefits of physical activity and weight reduction are tremendous. Losing weight is even associated with a reduction in C-reactive protein, an inflammatory protein associated with cardiovascular disease (Heilbronn, Noakes & Clifton, 2001; Ridker et al., 2000). In the past there has been concern about the risks of intense exercise, but the possibility of cardiac arrest or myocardial infarction during exercise is so low in healthy individuals that the benefits far outweigh any risk (Vuori, 1986; Whang et al., 2006). The main causes of death during exercise in young individuals are related to congenital and hereditary abnormalities. These may include hypertrophic cardiomyopathy, coronary artery abnormalities, or aortic stenosis. In high school and college athletes, the incidence of sudden death during exercises is only one per 133,000 men and one per 769,000 women (Van Camp et al., 1995).

The literature poses some general exercise guidelines to follow in order to achieve the most benefit, such as frequency, type and duration (American College of Sports Medicine, 2010; Garber et al., 2011). As for frequency, some individuals choose the route of what's called a *weekend warrior*. This is someone who performs little to no physical activity during the week but a large amount on the weekends. This pattern is indeed associated with reduced risk for disease and overall mortality, but only in individuals who don't already have cardiovascular disease risk factors (Lee et al., 2004).

Therefore, frequency of exercise does seem to hold some importance. Studies that looked at less than 150 min/wk of physical activity have generally noticed no change in the body weight of the individual, so volume is also important (Boudou et al., 2003; Campbell et al., 2007; Dengel et al., 1998). For mid to high level experienced weightlifters, resistance training at 60-80% of 1RM has proved very beneficial in gaining strength and muscle size (Wernbom, Augustsson, & Thomee, 2007). Stretching is also an important component to help reduce injury. Stretches should be held for 10-30 s to the point of slight discomfort (American College of Sports Medicine, 2010). Holding stretches for a longer period produces little extra benefit (Bandy, Irion, & Briggler, 1997). Proprioceptive neuromusculuar facilitation (PNF) stretching produces slightly greater gains in flexibility, but is impractical since it requires a partner (Sharman, Cresswell, & Riek, 2006). CrossFit® and the ACSM have both set forth a series of recommendations for how one should go about performing exercise.

## CrossFit® Recommendations

CrossFit® is unique in that it has no set workout pattern like the ACSM, but Greg Glassman (2002) suggests one pattern in his article *What Is Fitness?* He suggests beginning with a warm-up, and then performing 3-5 sets of 3-5 reps of a fundamental lift with ample rest followed by a metabolic conditioning circuit. Of course, this pattern is not the standard, and he urges trainers to be creative. Their cardiorespiratory training almost primarily involves weightlifting and gymnastics exercises. According to Greg

Glassman (2002), nature has no regard for the distinction between "cardio" and strength training . They accomplish their fitness goals through the use of interval and circuit training. They utilize this method in order to achieve gains in cardiorespiratory endurance while simultaneously maintaining muscular strength and power (Glassman, 2002). Greg Glassman also has recommendations for types of resistance exercises to be performed. Most bodybuilding or muscle isolation exercises such as curls, lateral raises, leg extensions and leg curls, according to Glassman (2002), don't belong in strength and conditioning programs because they have a lower neuroendocrine response as well as no function in everyday life. They propose that only multi-joint movements should be performed (Glassman 2002).

**ACSM Recommendations**

The ACSM is one of the most comprehensive authorities on how to properly implement exercise. The most up-to-date ACSM and American Heart Association (AHA) exercise recommendations were issued in 2007 and are listed in Table 4 (American College of Sports Medicine, 2010):

Table 4

*ACSM and AHA Exercise Recommendations*

| |
|---|
| All healthy adults aged 18 to 65 need moderate-intensity aerobic physical activity for a minimum of 30 min 5 days per week, or vigorous activity for a minimum of 20 min 3 days per week |
| Combinations of moderate and vigorous intensity exercise can be performed to meet this recommendation |
| Moderate-intensity aerobic activity can be accumulated toward the 30-min minimum by performing bouts each lasting 10 or more minutes |
| Every adults should perform activities that maintain or increase muscular strength and endurance a minimum of 2 days each week |
| Because of the dose-response relationship between physical activity and health, persons who wish to further improve their personal fitness, reduce their risk for chronic diseases and disabilities, or prevent unhealthy weight gain may benefit by exceeding the minimum recommended amounts of physical activity |

The baseline guidelines and recommendations of the ACSM only refer to the amount of physical activity needed to prevent weight gain and obesity. They don't necessarily mean that already overweight individuals will see weight loss from the guidelines (American College of Sports Medicine, 2010). Healthy individuals are those classified as low risk. They do not have signs/symptoms of or have diagnosed cardiovascular, pulmonary, and/or metabolic disease and have no more than one CVD risk factor. The risk of an acute cardiovascular event in this population is low, and a physical activity/exercise program may be pursued safely without the necessity for medical examination and clearance (American College of Sports Medicine, 2010).

The recommended frequency is at least 5 days/week of moderate intensity (40-60% $VO_2R$) aerobic (cardiorespiratory endurance) activities, weight-bearing exercise and flexibility exercise. Alternatively, at least 3 days/week of vigorous intensity ( > 60% $VO_2R$) aerobic activities, weight bearing exercise and flexibility exercise may be performed, or one may pursue 3-5 days/week combining the two (American College of Sports Medicine, 2010).

A single exercise session should include a warm-up, stretching phase, conditioning or sports-related exercise, and a cool-down. The warm-up should consist of a minimum 5 to 10 min of low ( < 40% $VO_2R$) to moderate (40-60% $VO_2R$) intensity cardiorespiratory and muscular endurance activity in order to increase the body's temperature and reduce post-exercise soreness. The conditioning phase includes any aerobic, resistance, or sports-related exercises such as treadmill running or weightlifting. The final phase is a cool-down, which involves 5 to 10 min of low intensity exercise to allow gradual recovery of heart rate and blood pressure to resting levels and help remove metabolic end products of intense exercise from the muscles (American College of Sports Medicine, 2010).

During the stretching phase, static stretches should be held 15-60 s (American College of Sports Medicine, 2010). Some studies have reported detrimental effects of stretching on muscular force and power, especially with static stretching, but the findings are inconclusive (Shier, 2001; Yamaguchi & Ishii, 2005).

The primary goal of resistance training should be to make activities of daily living, such as climbing stairs and carrying groceries, less physically stressful. To achieve this goal, individuals should resistance train each of the major muscle groups (chest, shoulders, upper and lower back, abdomen, hips and legs) 2-3 days/week, allowing at least 48 hr of rest before training the same muscle group again. Each muscle group should be trained for 2-4 sets with a rest interval of about 2-3 min in between sets. To improve muscular strength, mass and endurance, an individual should be able to perform an exercise for 8-12 repetitions, reaching a point of fatigue but not failure. This usually amounts to 60-80% of the individuals 1RM. If the goal of resistance training is endurance rather than strength, approximately 15-25 repetitions should be performed with shorter rest intervals (American College of Sports Medicine, 2010).

The type of cardiorespiratory exercise to be performed should be rhythmic and involve large muscle groups and require little skill to perform (American College of Sports Medicine, 2010). The proper intensity at which to perform cardiorespiratory exercise can be determined by heart rate calculations. The most popular formula for calculating an individual's maximum heart rate is 220 – age. However, Cleary and colleagues recommend the more accurate Gellish method, which is $HR_{max}$ = 206.9 – (0.67 x age) (2011). This newer formula is superior because the traditional formula tends to overestimate $HR_{max}$ in individuals younger than 40 and underestimate $HR_{max}$ in individuals older than 40 (American College of Sports Medicine, 2010). The heart rate reserve method more accurately reflects rate of energy expenditure and intensity than the simpler method of exercising at a percentage of $HR_{max}$ (American College of Sports Medicine, 2010).

Lastly, neuromuscular exercise such as pilates are recommended for certain populations. It is recommended mainly for older adults who are frequent fallers or with mobility impairments. For healthy adults it is only a suggestion (American College of Sports Medicine, 2010).

## Cardiorespiratory Fitness

Cardiorespiratory fitness is arguably the most important benefit to be achieved from exercise. The benefits of improving cardiorespiratory fitness are numerous. For example, improved cardiorespiratory fitness allows for longer and more intense exercise sessions, leading to greater short term benefits such as improved energy expenditure, blood lipids, blood pressure and glucose homeostasis (Thompson et al., 2001). Energy expenditure will be discussed more in the following sections.

In untrained individuals, it doesn't take high amounts of intensity to increase $VO_{2max}$. In trained individuals however, especially runners, it is necessary to regularly train at a much higher intensity. In a review of 59 studies, Midgley and colleagues (2006) found that aerobically fit individuals must perform interval training at 95-100% $VO_{2max}$ in order to see any improvement. A study which used a K4b2 Cosmed for measurements demonstrated that interval training up to 100% $VO_{2max}$ was most effective in achieving improvements in trained runners. Exercising above 100% $VO_{2max}$ resulted in too much blood lactate accumulation and fatigue (Billat et al., 2012).

Some of the performance increases from cardiorespiratory training are fairly easy to maintain, as it's been shown that intensities as low as 50% $VO_{2max}$ are sufficient to maintain mitochondrial improvements in Type I muscle fibers (Harms & Hickson, 1983). However, mitochondria respond more to exercise duration than intensity. After stopping training completely, stroke volume decreases rapidly to values similar to sedentary control groups. Maximum $O_2$ uptake will remain elevated several weeks longer due to greater arterial mixed venous oxygen difference (a-$vO_2$; Coyle et al., 1984).

Hickson, Bomze and Holloszy performed a series of studies investigating the amount of exercise needed to maintain $VO_{2max}$ in trained levels. In 1977, they found that it only took 5 days of training to elicit significant increases in heart rate and respiratory capacity. These capacities continued to improve linearly for 3 months, with

$VO_{2max}$ increasing on average by 0.12 L/min every week. Later in 1981, Hickson and Rosenkoetter discovered that he could reduce the participants' training frequencies by as much as 66% (6 days down to 2 days) and still maintain $VO_{2max}$ for at least 15 weeks. The same effect was noticed in 1982 when Hickson and Kanakis reduced the participants' training duration by the same 66% (40 min down to 13 min). The $VO_{2max}$ remained the same, but long-term cardiorespiratory endurance did decrease. However, long-term cardiorespiratory endurance did not decrease when duration was reduced by 33% (40 min down to 26 min). Then in 1984, Hickson, Overland and Dougherty noticed that in a study with rats and swimming, the rats' $VO_{2max}$ decreased significantly when training intensity was reduced. This led to a study in 1985 where Hickson and his colleagues performed the same protocol as previous studies, but reduced the participants' training intensity. With only a 33% decrease in intensity, $VO_{2max}$ and long term cardiorespiratory endurance decreased significantly, down to only slightly above pretraining levels (Hickson et al., 1985). Fox and colleagues (1975) also performed research analyzing the relationship between intensity and cardiorespiratory fitness improvements. In one study, participants were placed in groups training at the same intensities for 2 days/week and 4 days/week frequencies along 7 week and 13 week durations. They determined that $VO_{2max}$ was similarly improved across all groups, with exercise intensity being a greater factor in improvement over frequency and duration

(Fox et al., 1975). Longer duration training did, however, result in greater heart rate improvements.

**Vigorous vs. Moderate Intensity Exercise**

Many studies in the literature pose that performing exercise at a more vigorous intensity leads to greater health and fitness benefits. As long as the same amount of energy is expended in both modes of exercise, DiPietro and colleagues (2006) found greater improved glucose utilization in sedentary individuals performing vigorous exercise compared to moderate intensity exercise. Also at the same absolute energy expenditure, it has also been found that vigorous exercise elicits greater improvements in $VO_{2max}$ compared to moderate intensity exercise (Asikainen et al., 2003; DiPietro et al., 2006; Helgerud et al., 2007). There has also been some support that vigorous intensity exercise does reduce risk for cardiovascular disease to a greater degree than moderate intensity exercise, but only as long as the energy expended is equal (Haskell et al., 2007). It is actually unclear whether total volume of energy expended is related to reducing risk for cardiovascular and metabolic disease because most epidemiological studies have not examined this factor (Garber et al., 2011; Shephard, 2001).

Although there appear to be additional benefits to exercising at vigorous over moderate intensity, it is unclear at what point in intensity the benefits begin to accumulate, and at what point there might be diminishing returns. Further research is still needed to calculate the exact associations between intensity and reduced risk factors.

**Interval vs. Continuous Exercise**

Interval exercise involves performing alternating bouts of high and low intensity work, or alternating bouts of work and rest. Continuous exercise involves performing work at a steady state for a set amount of time. Both forms of training come with their own unique benefits. In a review by Garber and colleagues (2011) it was discovered that interval training has shown greater improvements in blood lipoproteins, glucose, interleukin-6, tumor necrosis factor α, muscle fatty acid transport and even $VO_{2max}$ over continuous exercise. These benefits were noted in studies with both healthy individuals and those with disease. As discussed in the previous section, this superiority may be due to interval trainings unique ability to be performed at more vigorous intensities. However, one study that used untrained men found that continuous exercise proved superior in enhancing resting heart rate levels, body composition and cholesterol levels to a greater degree than interval training (Nybo et al., 2010). It is unclear if similar results would be found in trained men.

One study by Gorostiaga and colleagues (1991) compared continuous vs. interval training. One group in the study performed 30 s of work at 100% $VO_{2max}$ alternated with 30 s of rest for 30 min, and the other group performed continuous work at 50% $VO_{2max}$

for 30 min continuously.  Both forms of training performed the same total volume of work, but at the end of the study, $VO_{2max}$ increased more in the interval group. However, continuous exercise was more effective at increasing muscle mitochrondrial activity (citrate synthase) and delaying the accumulation of blood lactate during maximal testing (Gorostiaga et al., 1991).  These findings are supported in earlier studies by Hickson and his colleagues (1982), where it was discovered that mitochondria respond more to exercise duration than intensity.

High-Intensity Interval Training (HIIT), which consists of short bouts of maximal aerobic work mixed with intervals of rest, can result in significant $VO_{2max}$, Wingate power output, muscle glycolytic and muscle mitochondrial activity improvements (Burgomaster et al., 2005).  Some studies show it has no effect on resting heart rate whereas others say it is improved (Astorino, 2010; Burgomaster et al., 2005).  Also, looking at the results of several studies, it does not appear to improve blood pressure (Astorino, 2010; Burgomaster et al., 2005).  Short-term effects following HIIT exercise include improved insulin action and fat usage, after only 16 min of exercise (Burgomaster, Heigenhauser, & Gibala, 2006).  One study has even shown that high-intensity interval training leads to greater health benefits than continuous training, even in patients with cardiovascular disease (Wisloff et al., 2007).  In the study by Wisloff and his colleagues, patients with stable postinfarction heart failure were randomly assigned to either a high intensity (95% peak heart rate) interval training group or moderate continuous group (70% peak heart rate). The higher intensity group experienced a greater degree of improvement in $VO_{2peak}$, arterial dilation and mitochondrial activity than the moderate continuous group.

Despite all these purported benefits, the effects of interval training have not been studied for longer than a 3-month timespan. More research is needed testing its effects over a longer period (Garber et al., 2011).

## Muscular Fitness

Another main benefit to exercise besides improving cardiorespiratory fitness is improving muscular fitness. Resistance training has many physiological benefits of its own. It has reported increases in HDL cholesterol, decreases in LDL cholesterol and triglycerides, and improved insulin sensitivity (Goldberg et al., 1984; Hurley et al., 1988; Ibanez et al., 2005). Heavy resistance exercise is also known to stimulate anabolic hormones in men, which would lead to greater amounts of muscle mass and an enhanced resting energy expenditure (Ahtiainen et al., 2003; Donnelly et al., 2009). In a study comparing types of resistance training, it was found that weight training with free weights rather than machines results in higher $VO_2$ values, and therefore greater energy expenditure (Monteiro et al., 2008).

It has generally been found that a weight training routine alone is not enough to elicit the recommended exercise intensity proposed by the ACSM, which amounts to a strain between 50-85% $VO_{2max}$ or 60-90% max heart rate (Beckham & Earnest, 2000; Wilmore et al., 1978). This lack of stress placed on the cardiovascular system results in a decreased caloric expenditure compared to cardiorespiratory exercise. Some studies have noticed no change in body weight with only resistance training, but some of these studies also did not measure body composition, so it's possible that fat mass was replaced with muscle (Hunter et al., 2002; Hurley et al., 1988; Klimcakova et al., 2006). One study observed that performing circuit weight training, where different exercises are performed with short intervals of rest at high loads, can lead to similar strength adaptations as typical weight training (Alcaraz et al., 2011). Furthermore, it can result in a greater enhanced body composition over traditional resistance training even though the total duration of exercise is less (Alcaraz et al., 2011).

The amount of repetitions performed in weight training also affects the benefits seen. A study by Campos and colleagues (2002) observed the effects of weight training at three different weight and repetition combinations. The low rep (4 sets of 3-5 reps) and intermediate rep (3 sets of 9-11 reps) saw significant improvement in strength and hypertrophy, whereas the high rep group (2 sets of 20-28 reps) saw improvements in aerobic power and muscular endurance. What's interesting is that the low rep group had equal improvements in hypertrophy as the intermediate group, but greater increases in strength.

## Combined Muscular and Cardiorespiratory Exercise

Physiologically, both cardiorespiratory and strength training are necessary for total body fitness. Strength training is required to improve activity of the glycolytic enzymes and muscle fiber contraction, and endurance training is required to increase muscle fuel stores, capillarization and mitochondrial density (Tanaka & Swensen, 1998). Actually, Tanaka and Swensen (1998) reviewed over 70 studies and concluded that training in only one modality reduces any benefits seen from the other. In a study performed by Hickson (1980), it was found that both endurance and strength improvements suffered significantly while performed simultaneously, but his procedures had his participants performing complete volumes of both. It was a lot of exercise, and participants were likely overtrained. One study by Hakkinen and colleagues (2003) implemented a program combining both endurance and strength training and did not notice the same detriments as Hickson (1980) noted. This was likely due to the fact that each modality was trained on a different day, rather than all at once. However, they did notice that explosive strength saw no increase when combined with endurance training (Hakkinen et al., 2003). For athletes who must perform powerful movements such as vertical jumps or Olympic lifts, it may be beneficial to periodize their training. Additionally, in a study by Alves and colleagues (2012), it was found that strength training and aerobic training can be performed in the same exercise session without negatively impacting the performance of the aerobic exercise. During combined arm and leg exercise, like found in CrossFit® or in circuit training, the heart is overly stressed trying to pump blood to all the working vasculature. In fact, sometimes there is vasoconstriction in the working muscle in order to maintain blood pressure (Secher et al., 1977). One may theorize that putting the heart under such a high stress could lead to greater $VO_2$ improvements than only performing movements with singular muscle groups, but this has yet to be tested.

## Energy Expenditure

For every liter of oxygen an individual uses per minute, they burn approximately 5 kcal (Brooks et al., 2005). A pound of fat contains 3500 kcal, so it takes significant energy expenditure and effort to burn only 1 lb of fat. At minimum, accumulating at least 1000 kcal of physical activity a week will result in health/fitness benefits, but energy expenditure exceeding 2000 kcal/week may be necessary in order to promote weight loss (American College of Sports Medicine, 2001). This adds up to 50-60 min/day of exercise as opposed to the baseline 30 min proposed by the ACSM (American College of Sports Medicine, 2010). To give a general idea of this workload, men can expend 525-1650 kcal/week and women can expend 420-1260 kcal/week by performing a brisk walk for 30 min on most days of the week. This amount of activity alone is enough to reduce cardiovascular disease mortality by 68% (Blair et al., 1989). In a Harvard Alumni Health Study examining 13,485 men, it was found that regular participation in light activities ( < 4 METS) had no effect on longevity, moderate activities (4-6 METs) were slightly effective in improving longevity, and vigorous activities ( > 6 METs) resulted in significant improvements in longevity. More specifically, men who expended less than 1000 kcal/week in physical activity were at high risk for all-cause mortality and those who expended 2000 kcal/week or more had a significantly reduced all-cause mortality (Lee & Paffenbarger, 2000).

In some cases, energy expenditure during physical activity is showing to be more important than the actual duration or intensity of the exercise. Several studies have actually reported that it is more so related to the calories expended during exercise rather than the duration of the exercise that elicits the health benefits, but this is inconclusive (Garber et al., 2011; Lee, Sesso, & Paffenbarger, 2000). Unfortunately, the general population tends to think they burn a lot more calories during exercise than they actually do (Willbond et al., 2010). Also, males tend to burn more calories than females during exercise due to their larger amounts of lean muscle mass. These differences dissipate when the calories burned are expressed relative to body weight (Beckham & Earnest, 2000). In essence, the kcal/bodyweight expended is more important than total kcal expended.

Sophisticated methods of measuring energy expenditure are required to estimate calories burned during exercise. One proposed method has been heart rate, but heart rate is a poor measure of energy expenditure unless used in a continuous exercise modality such as walking or running. It is ineffective at rest or during very high intensity exercise (Stec & Rawson, 2012).

**Excess Post Exercise Oxygen Consumption**

One major component in overall energy expenditure from exercise is EPOC. There appears to be both a fast and slow component to EPOC. The fast component lasts several minutes following exercise and is related to blood lactate accumulation and creatine rephosphorylation. The exact mechanism behind the slow component is unknown, but it is related to the magnitude of aerobic metabolism during the exercise (Binzen, Swan, & Manore, 2001; Gaesser & Brooks, 1984). Silva and colleagues (2010) found that EPOC is higher when rest periods between resistance exercises are shorter, or when individuals train at higher percentages of their 1RM. Therefore, increases in EPOC are directly related to the intensity of exercise. Meirelles and Gomez (2001) reviewed the literature and concluded that energy expenditure during the exercise session itself is more related to the volume of work, and not necessarily the intensity.

One study looked at interval training using high intensity interval resistance training versus traditional resistance training. It was found that even though much less time was spent in the interval resistance training, resting energy expenditure following exercise was substantially higher than in traditional resistance training ($2362 \pm 118$ vs. $1999 \pm 89$ kcal 22 hr after the exercise session; Paoli et al., 2012). A study by Silva and colleagues (2010) found that the order in which resistance exercises are performed does not alter EPOC, although it's undetermined as to whether it affects energy expenditure during the actual exercise. The EPOC had more to do with higher intensity work and shorter rest intervals.

**Pilot Study**

Prior to this study a pilot study involving four participants, three male and one female, was performed. The participants met the same qualifications as are defined in this research study, and they performed very similar exercise sessions. The workout template used for the pilot study can be found in Appendix C. All of the exercise sessions took 1 hr $\pm$ 3 min. Several changes were made to achieve a more accurate measure from each session. Previously, the individuals performed Back Squats in the ACSM session at 60% of their 1RM. This proved to be too heavy, so the percentage was lowered to 50%. Leg extensions were set at 100 lbs. for females and 150 lbs. for males, which also proved to be too heavy. The weights were lowered to 80 lbs. and 120 lbs., respectively. The cardiorespiratory portion of the ACSM session turned out to be too easy, working at 75% of max heart rate. For this study, the Gellish et al. method of max heart rate was used as it is more accurate than the traditional 220 – age (Cleary et al., 2011). Also, the participants performed their cardiorespiratory portion at 80% of their heart rate reserve. Blood pressure was also measured pre and post workout in the pilot study, but the values did not appear significantly different. However, blood pressure was measured after the 15 min recovery period rather than immediately following the exercise. For this study, blood pressure was measured immediately following the exercise session, as the participant begins their recovery walk. The results of the pilot study can be found in Appendix B.

# CHAPTER III

# METHODS

## Participants

This study called for 30 healthy, young volunteers, both male and female, to participate in two separate 1 hr warm-up, exercise and cool-down sessions. The participants were between 18-44 years of age and participated in some form of structured physical activity at least 3 hr a week for the past 6 months. Participants were classified as Low Risk in the ACSM risk stratification categories. This required that they did not have signs/symptoms of or have diagnosed cardiovascular, pulmonary, and/or metabolic disease and had no more than one CVD risk factor. Participants were instructed to perform no exercise on the day of the study or the day before. The meals/fluids they consumed for 12 hr beforehand were recorded so that they could consume the same meals/fluids before the second session. The investigator did not keep or observe the food records for confidentiality purposes, but the participants must have recorded those items so that they could be replicated for the second session. The participants also performed each session during the same time of day, within an hour of the time the original exercise session was performed. They also came in during the same time of day that they normally exercise. There was at least 1 week between the exercise sessions.

## Instruments and Equipment

Caloric expenditure was measured using a K4b2 Cosmed calorimeter. The K4b2 Cosmed performs indirect calorimetry using the Abbreviated Weir equation: Metabolic Rate = [3.9($VO_2$) + 1.1($VCO_2$)] 1.44 (COSMED 2008). Several studies have been performed testing the validity and reliability of the K4b2 Cosmed, typically by comparing it to values of $VO_2$, $VCO_2$, $V_E$ and caloric expenditure found in a metabolic cart (Bassett et al., 2001; Doyan et al., 2001; Duffield et al. 2004; McNaughton et al., 2005; Pinnington et al., 2001; Shrack et al., 2010; Stec & Rawson, 2012). The majority of studies have found that the values are not significantly different than a metabolic cart. Heart rate was measured using a Polar heart rate monitor. The warm-up and cardiorespiratory exercise were performed on a Startrac motorized treadmill. The back squats were performed using a squat rack, 45 lb. barbell and metal plates. The leg extensions were performed on a Cybex VR2 Leg Extension machine. Calf raises were performed on a raised platform. Kettlebell swings were performed using standard iron kettlebells. Blood pressure was measured using an arm cuff and sphygmomanometer.

## Procedures

### Introductory Session

Participants were instructed beforehand to wear exercise clothing and be prepared to perform back squats during their introductory session. Upon arrival to the introductory session, the participant filled out a PAR-Q. The PAR-Q may be found in Appendix D. The PAR-Q contained seven questions related to detection of heart disease symptoms and other contraindications to physical activity. If the participant answered "yes" to any question, he or she was instructed to contact a physician and was not able to participate in the study. The participant also filled out a form of Informed Consent, indicating they were aware of the risks and benefits associated with participation in the research study. The informed consent may be found in Appendix E. The investigator also helped the participant find their 1RM back squat, which was recorded in the Workout Template along with all of his or her other data (Appendix A). A 1RM back squat is the most weight a person can squat properly with a barbell across the back of their shoulders. A detailed description of the proper form can be found in the *Description of the Exercises* section. The investigator demonstrated the proper form to the participant, then instructed the participant in proper form with only the barbell. Weight was gradually added to the bar until the participant exerted themselves as hard as they could to properly squat the weight. The participant rested as long as they wanted between back squat attempts, but the entire process took no longer than 20 min. Age was also recorded along with age-predicted max heart rate. For this study, the Gellish method of maximum heart rate was used as it is more accurate than the traditional 220 – age (Cleary et al., 2011). The formula for max heart rate is as follows: $HR_{max} = 206.9 – (0.67 \times age)$.

**Anthropometric Measurements**

Height and body weight were measured prior to the first exercise session. Body weight was measured again before the second exercise session. Body weight was measured to the nearest 0.1 kg and obtained while the participant stood with no shoes on a Tanita BWB-800 Digital Scale. Height was measured using a stadiometer to the nearest 0.1 cm and obtained while the participants were barefoot and looking straight forward.

**Preliminary Procedures**

The participant performed both a CrossFit® and ACSM exercise and recovery session. The order in which they were performed was randomized using the Microsoft Excel random function. Participants were asked to avoid any exercise the day of and day before the session, record their foods/fluids consumed for the 12 hr preceding the session, and avoid heavy meals 2-3 hr before the sessions. For the 12 hr before the second session they were asked to consume the same food/fluids as they did during the previous session. Each participant began the ACSM session by affixing a Polar heart rate monitor strap around their chest in the privacy of a restroom. They also wore the Polar heart rate monitor wrist watch. The wrist watch was not required for the CrossFit® session because heart rate did not need to be actively monitored. A K4b2 Cosmed unit was used to collect participant data including oxygen consumption, carbon dioxide production, heart rate and ventilation. A face mask was securely fitted to each participant to ensure no gas escape occurred. The K4b2 Cosmed unit was attached to each participant using a harness which was adjusted to allow for minimal obstruction of movement. The participant had a chance to ask questions and practice exercises if he or she desired. The descriptions of the exercises performed may be found later in this chapter.

**CrossFit® Session**

Before the 45 min exercise session began the investigator started the time on a digital stopwatch and obtained resting blood pressure, heart rate, oxygen consumption, carbon dioxide production and ventilation data with the K4b2 Cosmed while the participant was at rest in a seated position for a period of 5 min. The participants' resting heart rate was recorded after the 5 min. The investigator recorded the time on the stopwatch, then a warmup was performed involving a jog at 5 mph for 3 min on a Startrac® motorized treadmill at 0% grade. Participants were instructed to step onto the treadmill and place their hands on the siderails while the investigator steadily increased the speed to 5 mph. After finishing the jog and stepping off the treadmill, the participants then performed a series of dynamic stretches: 10 arm circles on each arm, 10 hip swings on each leg and 5 inch worms. The participant then performed warm-up sets of back squats. The first set was 10 reps with an empty 45 lb. barbell, then 1 set of 8 repetitions at 40% 1RM, and then 1 set of 6 repetitions at 60% 1RM. The investigator adapted this warmup regime from personal knowledge; it was not adapted from any research. The rest time between warmup sets was only to add more weight, and was not calculated. They then performed 5 sets of 5 repetitions at 75% 1RM, with 3 min rest between each set, as indicated by the investigator's stopwatch. After the back squats, the weights were put away then the investigator and participant moved to an indoor track. The participant then performed as many rotations as possible in 15 min of: Run 2 laps around the track (324 m total), 10 up-and-downs, 15 Kettlebell Swings (25 lbs. for female participants and 45 lbs. for male participants). This 15 min of conditioning is referred to as a "metcon" in the CrossFit® community, which is short for metabolic conditioning. After the 15 min, the investigator recorded the time on his or her stopwatch and had the participant walk around the track at a 3 mph pace for 5 min. This began the 15 min recovery phase. The 3 mph pace was determined by setting pieces of tape 10 m apart on the track, and walking to each piece of tape in 7.5 s as determined by the investigators stopwatch. The investigator practiced this pace beforehand and walked with the participant during this time. As the participant was walking the investigator attached an arm cuff to the participant's bicep and used a sphygmomanometer on the brachial artery to obtain systolic and diastolic blood pressure measurements. After 5 min of walking, the participant sat down for 10 min. At this point the session was over, and the investigator aided the participant in removing the face mask and harness.

**Traditional Session**

The workout session performed under ACSM prescriptions will be referred to as the "traditional" workout. Before the 45-min exercise session began the investigator started the time on a digital stopwatch and obtained resting blood pressure, heart rate, oxygen consumption, carbon dioxide production and ventilation data with the K4b2 Cosmed while the participant was at rest in a seated position for a period of 5 min. The participants' resting heart rate was recorded after the 5 min. The resting heart rate was used to calculate 80% of the participant's heart rate reserve. The ACSM recommends working at 60-80% heart rate reserve for 20-60 min per aerobic session (American College of Sports Medicine, 2010). Since this procedure calls for the minimum 20 min, participants were kept around the upper level of 80% heart rate reserve. The formula for heart rate reserve at 80% intensity is as follows: Target HR = $[(HR_{max} – HR_{rest}) X 0.8] + HR_{rest}$. The investigator recorded the time on the stopwatch, then a warmup was performed involving a jog at 5 mph for 3 min on a Startrac® motorized treadmill at 0% grade. Participants were instructed to step on the treadmill and place their hands on the siderails while the investigator steadily increased the speed to 5 mph. Following the treadmill warmup, the participants performed a series of static stretches: 20 s quad stretch each leg, 30 s hamstring stretch and 20 s calf stretch each leg. The participant then performed 1 set of 10 back squats with an empty 45 lb. barbell as a warmup. The participant then performed 3 sets of 10 repetitions at 50% of their 1RM, with 1 min rest between sets as indicated by the investigator's stopwatch. After finishing, the participant and investigator put the weights away, and then the participant performed 3 sets of 10 repetitions of leg extensions using a Cybex VR2 Leg Extension with 1 min rest between sets. The weight on the leg extensions were determined by the participant's 1RM back squat. If their back squat was 300 lbs. or more, the weight was 130 lbs. If they squat 200-299 lbs, the weight was 100 lbs. If they squat 100-199 lbs, the weight was 70 lbs. Lastly, if they squat less than 100 lbs, the weight was 40 lbs. The prescriptions for these weights are based on the investigators personal knowledge; they are not adapted from any research. After the third set, the participant performed 1 set of 20 calf raises on each leg utilizing an elevated platform. The participant then performed cardiorespiratory exercise on a Startrac® motorized treadmill. The instructor set a timer for 20 min, then the participant began by walking at a 3% grade at 3 mph, and the instructor increased the speed by 0.5 mph every minute until the participant reached 80% of his or her heart rate reserve. The investigator adjusted the speed as needed to keep the participant within 5 beats of their target heart rate. Once the 20 min was over, the investigator recorded the total workout time displayed on the stopwatch, and the 15 min recovery period began. The participant began walking on the treadmill at 3 mph and 0% grade for 5 min. As the participant was walking the investigator attached an arm cuff to the participant's bicep and used a sphygmomanometer on the brachial artery to obtain systolic and diastolic blood pressure measurements.  Following 5 min of walking he or she sat down on a bench for 10 min.  At this point the session was over, and the investigator aided the participant in removing the face mask and harness, and the participant moved to the privacy of a bathroom to remove the Polar heart rate monitor.

**Measurements**

During both exercise and recovery sessions, metabolic equivalent levels, heart rate, oxygen consumption, carbon dioxide production, ventilation, and respiratory exchange ratio were recorded on a breath-by-breath analysis using a portable telemetric apparatus or K4b2 Cosmed.  This consists of a harness worn on the chest on which an oxygen-analyzer-transmitter (13 x 9 x 4 cm) is fixed on the participant's back and a battery (13 x 9 x 2 cm) on the front, for a total mass of 800 g.  An oro-nasal mask, with a turbine of measurements of ventilator flow rate, is fixed on the participant's face. Gas samples are streamed to a micro mixing chamber for analysis and a receiver unit recorded the data.  Prior to testing, the K4b2 Cosmed flow meter was calibrated with a 3-L syringe, and the oxygen analyzer was calibrated with a known gas mixture (16% $O_2$ and 4% $CO_2$) and environmental air (20.93% $O_2$ and 0.03% $CO_2$).  The data was later downloaded and analyzed using the K4b2 computer program.

## Description of the Exercises

Quad Stretch: The participant held onto a stationary object, reached back, and pulled an ankle up to their buttocks so that a comfortable amount of tension was felt in their quadriceps muscles.

Hamstring Stretch: The participant stood with their feet together, kept their legs straight, and reached down towards their toes until a comfortable amount of tension was felt in their hamstring muscles.

Calf Stretch: The participant faced a wall, planted their palms against the wall, then stepped one leg forward and the other backward in a lunge position, keeping their back leg straight so that a comfortable amount of tension was felt in their calf muscles.

Back Squat: The participant started by placing a barbell on a rack (set to shoulder height), then they placed their hands at an even distance from the center of the barbell. They then stepped underneath and rested the barbell on their shoulders. They then stood up so the weight was lifted from the rack and took 2 steps backwards. The participant placed their feet shoulder width apart and pointed their toes out at a $30^{o}$ angle. Their knees pointed in the same direction as their toes throughout the entirety of the exercise. They sat their hips back, keeping their feet flat on the floor, and lowered their hips until their pelvis fell below the height of their knee. They then stood all the way back up to a full upright position.

Leg Extension: The participant sat on the leg extension machine so that the pad rested on the front of their ankles and their knee joint was at a 60$^o$ angle. They then smoothly straightened their legs until full contraction was achieved, then smoothly lowered back down to the starting position.

Calf Raise: The participant stood with the ball of their foot on an elevated platform, heel hanging off the edge, with a support structure to hold onto. The other leg was held up in a gently flexed position. They started relaxed at the bottom position, smoothly raised up until they are were high as they could go, and then smoothly lowered back down to the starting position.

Arm Circle: The participant rotated their arm in a full 360$^o$ circle along the perpendicular plane of their body, going backwards and forwards.

Hip Swing: The participant held onto a support structure and kicked one leg back and forth along the perpendicular plane of their body.

Inch Worm: The participant reached down towards their toes, touched their hands to the ground, and then steadily walked their hands away from their body until they were in a pushup position. They then performed one complete pushup, touching their chest to the ground then pushing back up, then walked their hands backwards towards their feet so they were back in the starting position.

Up-and-Down: The participant reached down towards their toes and planted their hands on the ground. They then jumped their feet backwards so that they were in a pushup position. They then jumped their feet back up towards their hands and the participant stood all the way back up to a standing position. Once the participant stood up, they fully stretched their arms above their head and jumped off the ground slightly. The participant then lowered their arms back down to the starting position.

Kettlebell Swing: The participant stood with their feet shoulder width apart and their toes pointed out at a $30^{o}$ angle with the kettlebell between their feet. Keeping a neutral spine, they bent over and picked up the kettlebell with both hands, holding the handle with their palms facing backwards. To initiate the exercise, they protruded their hips backwards then forcefully contracted their hamstring and glute muscles in order to propel the kettlebell forward. Keeping their arms straight, the participant guided the kettlebell forward until their arms were fully extended over their head. Once overhead, they guided the kettbell back down to the starting position. There was no pause between repetitions; one repetition was performed right after the next.

## Statistical Analysis

Differences in caloric expenditure were measured using a Dependent t-Test, looking at the difference between calories expended during traditional exercise and during CrossFit® exercise. A Dependent t-Test was also used to compare the differences in peak $VO_2$'s and peak heart rates between the sessions. A Dependent t-Test was used to compare the average 15 min recovery $VO_2$'s from each workout.

# CHAPTER IV

# RESULTS

## Description of the Participants

A total of 30 participants took part in this study (15 men and 15 women). Participants ranged between the ages of 19-44 yrs with an average age of 28 ± 6 yrs. All participants signed an IRB-approved informed consent (located in Appendix E) and answered "no" to all questions on a Physical Activity Readiness Questionnaire (located in Appendix D). All participants were physically active for at least 1 hr on at least 3 days/week for the past 6 months or more, and had no injuries or other conditions that barred them from exercise. Twenty-two of the participants actively participated in CrossFit® as their primary exercise program. The remaining eight participants did not perform CrossFit® as their primary exercise program, but they were all familiar with it, and several had tried it in the past. The 22 CrossFit®-trained participants were recruited from a local CrossFit® gym. The remaining participants were recruited through word-of-mouth or fliers placed on the TWU campus. Data describing the participants may be found in Appendix F. Characteristics of the participants may be viewed in Table 5.

Table 5

*Characteristics of the Participants*

| Characteristic | Mean ± SD |
|---|---|
| Age (yrs) | 28 ± 6 |
| Height (cm) | 169 ± 9 |
| Weight (kg) | 74 ± 16 |
| Age-Predicted Max HR (bpm) | 188 ± 4 |
| 1RM Back Squat (kg) | 100 ± 36 |

n=30

## Description of the Workout Sessions

Workout and recovery session times ranged from 59 min and 55 s to 1 hr 5 min and 13 s for the CrossFit® workout and 56 min and 25 s to 1 hr 2 min and 30 s for the traditional workout. The CrossFit® workout and recovery time lasted on average 1 hr 2 min and 10 s ± 1 min and 13 s, and the traditional workout and recovery time lasted on average 59 min and 32 s ± 1 min and 28 s. Data describing the workout sessions may be found in Appendix F. Descriptions of the workout sessions may also be viewed in Table 6.

Table 6

*Description of the Workout Sessions*

| Workout | Mean Session Length ± SD |
|---|---|
| CrossFit® | 1 hr 2 min 10 s ± 1 min 13 s |
| Traditional | 59 min 32 s ± 1 min 28 s |

**Traditional vs. CrossFit® Energy Expenditure**

Total energy expenditure (exercise plus recovery) ranged from 326-693 kcal in the CrossFit® workout and 327-609 kcal in the traditional workout. The CrossFit® workout had an average energy expenditure of 468 ± 116 kcal and the traditional workout averaged 431 ± 96 kcal. Energy expenditure was significantly greater ($t = 6.131$, $p < .001$) during the CrossFit® workout compared to the traditional workout. Energy expenditure between the two sessions may be compared in Figure 1. Total energy expenditure for men in the CrossFit® workout ranged from 414-693 kcal, with an average of 563 ± 87 kcal. The energy expenditure for men in the traditional workout ranged from 371-609 kcal, with an average of 505 ± 82 kcal. Total energy expenditure for women in the CrossFit® workout ranged from 326-442 kcal, with an average of 373 ± 31 kcal. The energy expenditure for women in the traditional workout ranged from 327-430 kcal, with an average of 357 ± 26 kcal. All data regarding energy expenditure may be found in Appendix F.

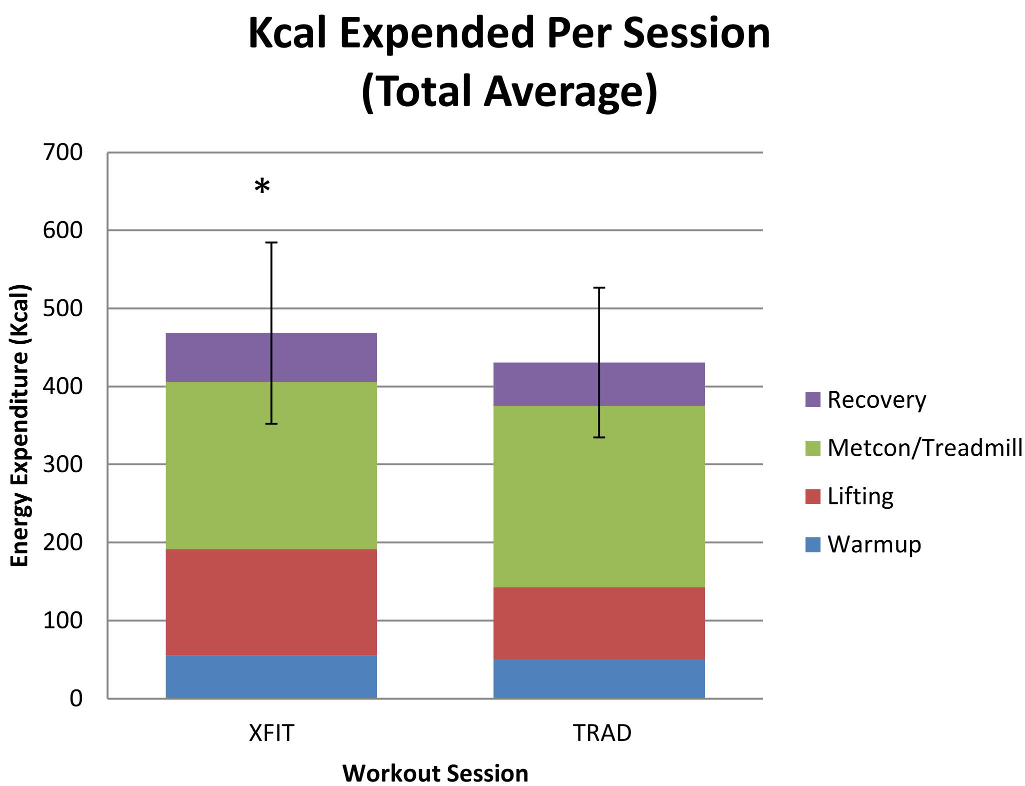


*Figure 1*. Kcal expended per session (total average). The "XFIT" column represents calories expended during the CrossFit® workout and the "TRAD" column represents calories expended during the traditional workout. The "Warmup" bar represents calories expended during the rest and warmup phase of each session. The "Lifting" bar represents the strength training phase of each session. The "Metcon/Treadmill" bar represents the metcon for the CrossFit® workout and the treadmill run for the traditional workout, respectively. The "Recovery" bar represents the 5 min cooldown walk and 10 min sit of each session. * Energy expenditure was significantly greater ($p < .001$) during the CrossFit® workout compared to the traditional workout.

**Traditional vs. CrossFit® Average $VO_2$**

The average $VO_2$ across the 1 hr CrossFit® session ranged from 1.07-2.19 L/min with an average of 1.53 ± 0.37 L/min. Average $VO_2$ across the 1 hr traditional session ranged from 1.08-2.1 L/min with an average of 1.48 ± 0.34 L/min. For men, average $VO_2$ for the CrossFit® workout ranged from 1.36-2.19 L/min with an average of 1.83 ± 0.29 L/min. Average $VO_2$ of the traditional workout in men ranged from 1.27-2.1 L/min with an average of 1.74 ± 0.3 L/min. For women, average $VO_2$ for the CrossFit® workout ranged from 1.07-1.5 L/min with an average of 1.23 ± 0.11 L/min. Average $VO_2$ of the traditional workout in women ranged from 1.08-1.54 L/min with an average of 1.23 ± 0.11 L/min. Average $VO_2$'s may be compared in Figure 2. All data regarding average $VO_2$ may be found in Appendix F.

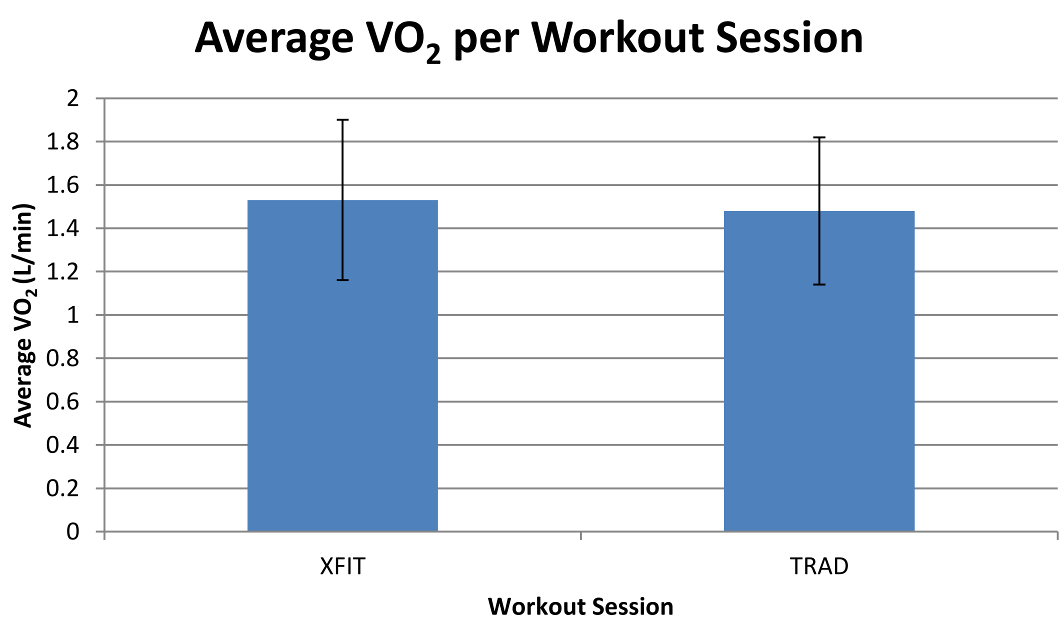


*Figure 2*. Average $VO_2$ per Workout Session. The "XFIT" column represents the average $VO_2$ of the CrossFit® workout and the "TRAD" column represents the average $VO_2$ of the traditional workout.

**Traditional vs. CrossFit® Energy Expenditure Per Minute**

Energy expenditure per minute for the CrossFit® workout was between 5.2-11.0 kcal/min with an average of 7.5 ± 1.8 kcal/min. Energy expenditure for the traditional workout was between 5.4-10.2 kcal/min with an average of 7.3 ± 1.6 kcal/min. Energy expenditure per minute was significantly greater (t = 3.351, p = .002) during the CrossFit® workout compared to the traditional workout. Energy expenditure per minute for each session may be compared in Figure 3. For men, energy expenditure per minute for the CrossFit® workout was between 6.8-11.0 kcal/min with an average of 9.0 ± 1.4 kcal/min. Energy expenditure per minute for the traditional workout in men was between 6.3-10.2 kcal/min with an average of 8.5 ± 1.4 kcal/min. For women, energy expenditure per minute for the CrossFit® workout was between 5.2-7.3 kcal/min with an average of 6.0 ± 0.5 kcal/min. Energy expenditure per minute for the traditional workout in women was between 5.4-7.4 kcal/min with an average of 6.0 ± 0.5 kcal/min. All data regarding energy expenditure per minute may be found in Appendix F.

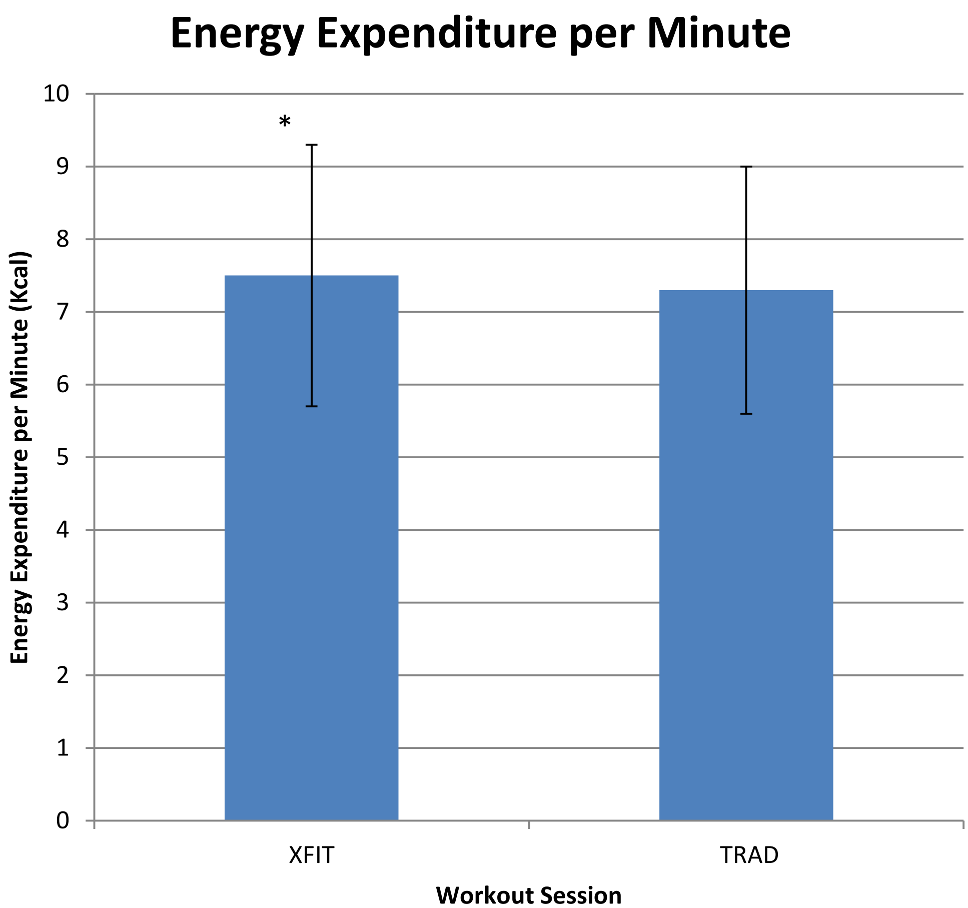


*Figure 3*. Energy expenditure per minute. The "XFIT" column represents calories expended per minute during the CrossFit® workout and the "TRAD" column represents calories expended per minute during the traditional workout. * Energy expenditure per minute was significantly greater ($p = .002$) during the CrossFit® workout compared to the traditional workout.

**Traditional vs. CrossFit® Average 15 min Recovery $VO_2$**

The 15 min Recovery $VO_2$ began collecting immediately following the metcon of the CrossFit® workout and following the treadmill run in the traditional workout. The average $VO_2$ per minute was calculated and compared between workouts using a

Dependent t-Test. During the first 5 min of recovery the participant was performing a walk at 3 mph, and then during the final 10 min the participant was sitting down. The average recovery $VO_2$ for the CrossFit® session ranged from 0.52-1.32 L/min with an average of 0.89 ± 0.24 L/min. The average recovery $VO_2$ for the traditional session ranged from 0.55-1.16 L/min with an average of 0.78 ± 0.18 L/min. The CrossFit® workout had a significantly higher average 15 min Recovery $VO_2$ ($t = 5.044$, $p < .001$) over the traditional workout. Fifteen min Recovery $VO_2$ for each session may be compared in Figure 4. For men, recovery $VO_2$ for the CrossFit® session ranged from 0.74-1.32 L/min with an average of 1.06 ± 0.2 L/min. Recovery $VO_2$ for the traditional session in men ranged from 0.62-1.16 L/min with an average of 0.91 ± 0.16 L/min. For women, recovery $VO_2$ for the CrossFit® session ranged from 0.52-0.9 L/min with an average of 0.71 ± 0.1 L/min. Recovery $VO_2$ for the traditional sesion in women ranged from 0.55-0.86 L/min with an average of 0.65 ± 0.08 L/min. All data regarding average 15 min recovery $VO_2$ may be found in Appendix F.

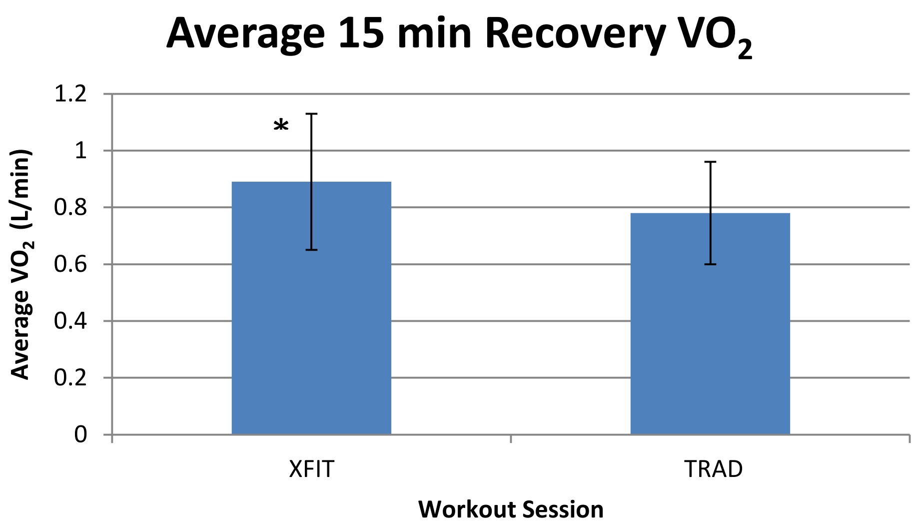


*Figure 4*. Average 15 min recovery $VO_2$. The "XFIT" column represents the average 15 min recovery $VO_2$ of the CrossFit® workout and the "TRAD" column represents the average 15 min recovery $VO_2$ of the traditional workout. * The average 15 min Recovery $VO_2$ was significantly greater ($p < .001$) during the CrossFit® workout compared to the traditional workout.

**Traditional vs. CrossFit® Mean Arterial Blood Pressure**

Systolic and diastolic blood pressure measurements were performed during the 5-min sit preceding the warmup of each exercise session, and then immediately following the metcon/treadmill run of each exercise session. Mean arterial blood pressure (MAP) was calculated using [$^1/_3$* Systolic] + [$^2/_3$ * Diastolic]. The mean arterial blood pressures ranged from 72 mmHg to 105.3 mmHg (average 88.2 ± 8 mmHg) before the CrossFit® workout and from 77.3 mmHg to 114 mmHg (average 91.1 ± 8.9 mmHg) before the traditional workout. The mean arterial blood pressures ranged from 78 mmHg to 118.7 mmHg (average 91.4 ± 9.3 mmHg) following the CrossFit® metcon and from 74 mmHg to 102 mmHg (average 90 ± 8.3 mmHg) following the treadmill run. Mean arterial blood pressures may be compared in Figure 5. The mean arterial blood pressures for men ranged from 82.7 mmHg to 105.3 mmHg (average 92.6 ± 6.9 mmHg) before the CrossFit® workout and from 83.3 mmHg to 114 mmHg (average 96 ± 7.6 mmHg) before the traditional workout. The mean arterial blood pressures for men ranged from 78 mmHg to 118.3 mmHg (average 93.7 ± 11 mmHg) following the CrossFit® metcon and from 84 mmHg to 102 mmHg (average 95.5 ± 5.5 mmHg) following the treadmill run. The mean arterial blood pressures for women ranged from 72 mmHg to 92.7 mmHg (average 83.9 ± 6.6 mmHg) before the CrossFit® workout and from 77.3 mmHg to 102 mmHg (average 86.3 ± 7.6 mmHg) before the traditional workout. The mean arterial blood pressures for women ranged from 80.7 mmHg to 104.7 mmHg (average 89 ± 6.8 mmHg) following the CrossFit® metcon and from 74 mmHg to 97.3 mmHg (average 84.6 ± 6.9 mmHg) following the treadmill run. All data regarding systolic, diastolic and mean arterial blood pressures may be found in Appendix F.

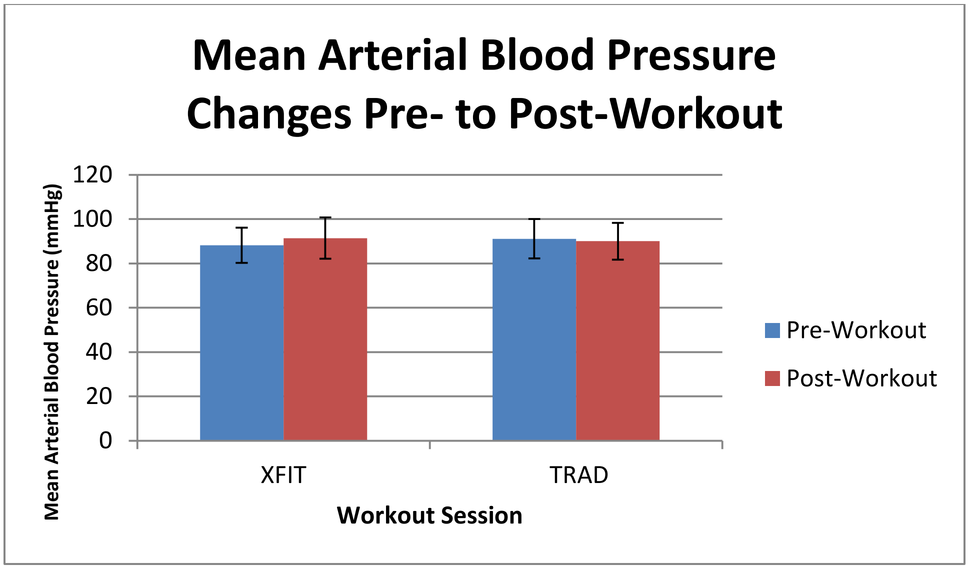


*Figure 5*. Mean arterial blood pressure changes pre- to post-workout. The "XFIT" columns represent the pre and post mean arterial blood pressures during the CrossFit® workout and the "TRAD" columns represent the pre and post mean arterial blood pressures during the traditional workout.

**Traditional vs. CrossFit® Peak Heart Rate**

During the CrossFit® workouts, the participant's peak heart rate was always achieved during the metcon. During the traditional workouts, most of the participants achieved their peak heart rate while they were on the treadmill, although several participants surpassed that following the 3 sets of 10 back squats. Peak heart rates during the CrossFit® workout ranged from 176-208 bpm with an average of 189 ± 8 bpm. Peak heart rates during the traditional workout ranged from 160-194 bpm with an average of 172 ± 8 bpm. The CrossFit® workout had a statistically significant ($t = 11.360$, $p < .001$) elevated peak heart rate over the traditional workout. Peak heart rates between the sessions may be compared in Figure 6. For men, peak heart rates during the CrossFit® workout ranged from 176-198 bpm with an average of 187 ± 7 bpm. Peak heart rates during the traditional workout ranged from 160-194 bpm with an average of 171 ± 10 bpm in men. For women, peak heart rates during the CrossFit® workout ranged from 181-208 bpm with an average of 192 ± 8 bpm. Peak heart rates during the traditional workout ranged from 164-181 bpm with an average of 173 ± 5 bpm in women. All data regarding heart rate may be found in Appendix F.

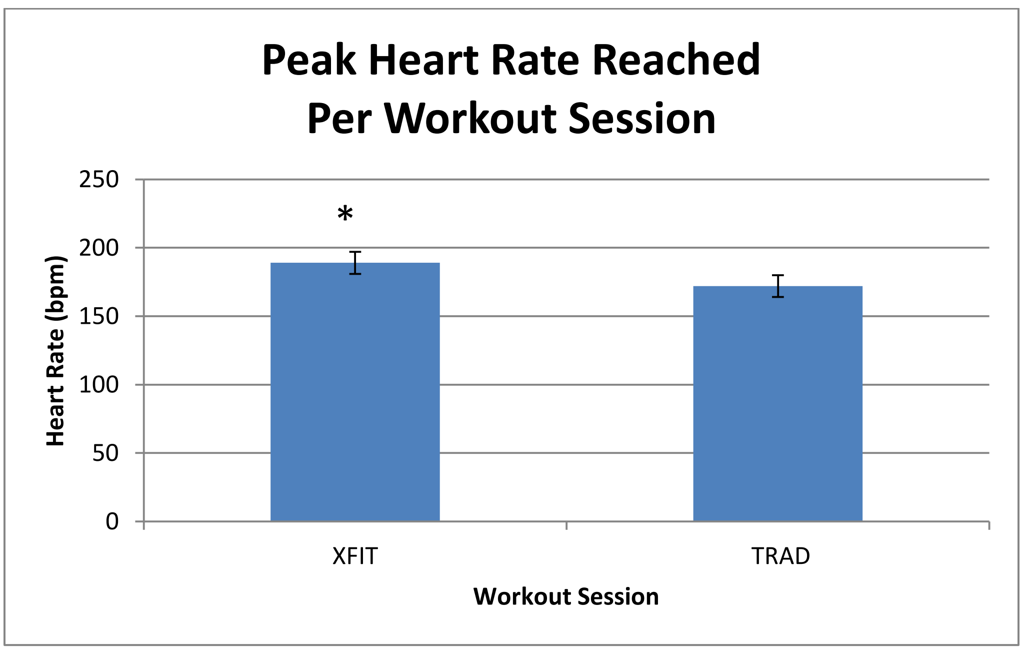


*Figure 6*. Peak heart rate reached per workout session. The “XFIT” columns represents the peak heart rate reached during the CrossFit® workout and the “TRAD” columns represents the peak heart rate reached during the traditional workout. * Peak heart rate was significantly greater ($p < .001$) during the CrossFit® workout compared to the traditional workout.

## Traditional vs. CrossFit® Peak $VO_2$

Peak $VO_2$'s achieved during the CrossFit® workout ranged 2.3-4.61 L/min from with an average of 3.22 ± 0.73 L/min. Peak $VO_2$'s achieved during the traditional workout ranged from 2.11-4.17 L/min with an average of 2.81 ± 0.63 L/min. The peak $VO_2$ achieved was significantly greater ($t = 8.683$, $p < .001$) during the CrossFit® workout compared to the traditional workout. Peak $VO_2$'s achieved between the sessions may be compared in Figure 7. For men, peak $VO_2$'s achieved during the CrossFit® workout ranged from 2.74-4.61 L/min with an average of 3.8 ± 0.58 L/min. Peak $VO_2$'s achieved during the traditional workout ranged from 2.33-4.17 L/min with an average of 3.26 ± 0.6 L/min in men. For women, peak $VO_2$'s achieved during the CrossFit® workout ranged from 2.3-3.19 L/min with an average of 2.65 ± 0.26 L/min. Peak $VO_2$'s achieved during the traditional workout ranged from 2.11-2.92 L/min with an average of 2.36 ± 0.21 L/min in women. All data regarding peak $VO_2$'s may be found in Appendix F.

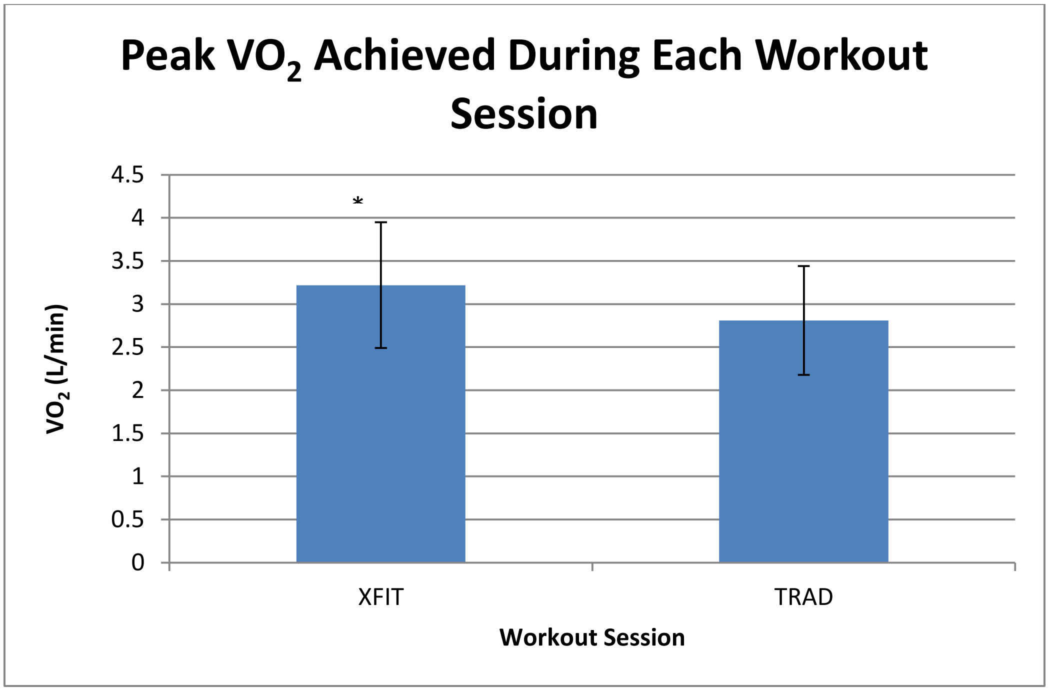


*Figure 7*. Peak $VO_2$ achieved during each workout session. The "XFIT" columns represents the peak $VO_2$ achieved during the CrossFit® workout and the "TRAD" columns represents the peak $VO_2$ achieved during the traditional workout. * Peak $VO_2$ was significantly greater ($p < .001$) during the CrossFit® workout compared to the traditional workout.

**Replacement of Missing Values**

On three occasions the K4b2 Cosmed's battery pack died during the workout session. The investigator was aware of this and replaced the battery pack immediately. Once the battery is replaced, the testing resumed as normal. Through further investigation of the data, it appears that the Cosmed was still collecting data even during battery replacement. The data collected while the battery was dead follows the same pattern as the data collected in the previous and following minutes of data collection. Data during these brief time periods may not be exact, but no attempts were made to change any of the data or replace any of those missing data points.

A number of heart rate values for three of the participants are clearly incorrect through further investigation of the data. It is possible that during the metcon or treadmill running that the Polar heart rate monitor slid down from the optimal location on the sternum. This was enough of an issue for two of the participants that the investigator had to manually check heart rate at the radial artery periodically during the treadmill run. No attempt was made to replace incorrect/missing heart rate values. These participants were not included in the data or statistical analysis for peak heart rate.

CHAPTER V

# DISCUSSION

## Conclusion on Hypotheses

Based on the statistics, the author may reject the null hypothesis that there is no significant difference in energy expenditure between the traditional and CrossFit® workouts. The CrossFit® workout expended more calories than the traditional workout. The difference remains when total calories are calculated compared to calories expended per minute.

The author may reject the null hypothesis that there is no significant difference in average $VO_2$ during the 15 min recovery portion of each workout. The CrossFit® workout had a significantly higher average $VO_2$ than the traditional workout.

The author may also reject the null hypothesis that there is no significant difference between peak $VO_2$ and heart rate between each workout. The CrossFit® workout had a significantly higher peak $VO_2$ and heart rate than the traditional workout.

## Summary of Differences in Results

### Energy Expenditure

Based on the data, it is clear that the participants expended more calories in the CrossFit® workout than the traditional workout. With the average energy expenditure of the CrossFit® workout at 468 ± 116 kcal, CrossFit® exercise on 3-4 days/wk seems more than sufficient to meet the ACSM's recommended exercise energy expenditure of 1200-2000 kcal/wk in order to prevent weight gain (ACSM, 2010). Looking at the average energy expenditure per workout, the CrossFit® workout averaged 37 kcal more than the traditional workout. Such an amount is negligible for one workout session, but if performed 3 days/wk, it could lead to a difference of 444 kcal over the course of a month and 5328 kcal over the course of a year.

### Average $VO_2$, 15 min Recovery $VO_2$, Peak Heart Rate and Peak $VO_2$

The average $VO_2$ during the entire 1 hr session appeared to be higher in the CrossFit® workout, although no statistics were performed on this data. It is interesting to note that average $VO_2$ across each session was exactly the same in women. There was a higher average $VO_2$ during the 5 min walk and 10 min sitting portion of the CrossFit® workout than the traditional workout. This could be accredited to the greater intensity of the metcon over the treadmill run. Heart rate and $VO_2$ values were both significantly higher during the metcon than during the treadmill run. These results are similar to the findings of multiple research studies. Silva and his colleagues (2010) and Binzen, Swan and Manore (2001) concluded that higher intensity exercise leads to a higher short-term recovery $VO_2$ than lower intensity exercise. It is possible that the higher short-term recovery $VO_2$ also means that the CrossFit® workout expends more calories 1, 2 or 3 hr post-workout, although more research is needed to prove this. Borsheim and Bahr (2003) suggest that training status and possibly gender both have an effect on recovery $VO_2$ and prolonged elevated energy expenditure beyond just the mode, duration and intensity of the exercise. It must also be noted that resistance training was performed before the conditioning portion of each workout, which may have had an effect on the 15-min recovery. According to research performed by Silva, Brentano and Kruel (2010), it is still unclear if performing both resistance and endurance training in the same workout affects EPOC. They posed that the intensity of the resistance training may have an effect. If this is true, then the 15-min recovery $VO_2$ of the traditional workout may have been slightly elevated due to the higher intensity of the resistance training during that session. According to Beckham and Earnest (2000), performing resistance training alone is sufficient to result in higher VO2 and fat oxidation up to 2 hr post workout, so it's quite possible it affected the recovery $VO_2$ of the present study.

One interesting thing to note is that Minute 2 of recovery for both sessions were not significantly different from one another. This could be attributed to the manner in which blood pressure was collected at the beginning of the recovery period. Immediately following the treadmill run, the treadmill speed was reduced to 3mph and the researcher measured blood pressure as they continued to walk. Immediately following the metcon in the CrossFit® workout, the participant had to stop moving briefly as the researcher measured blood pressure, then the cooldown commenced as normal. This stoppage after the metcon is likely what led to Minute 2 of each workout being similar, despite every other minute of recovery being significantly higher in CrossFit®. This could be controlled in future studies by briefly having the participant in the treadmill run stop moving during blood pressure measurement as well.

**Mean Arterial Blood Pressure**

Blood pressure was measured before and immediately following the metcon/treadmill portion of each workout, then the subsequent increase or decrease in mean arterial blood pressure was calculated. On average, mean arterial blood pressure rose slightly following the CrossFit® workout and fell slightly following the traditional workout. The steady pace on the treadmill led to relatively small blood pressure changes overall, but the high intensity of the metcon led to some significant changes. Systolic blood pressures rose much higher after the metcon than after the treadmill run, but diastolic pressures also fell to a greater degree. Statistics were not performed on the mean blood pressure values; more research is required to see if these differences are significant.

During the pilot study, blood pressure values were measured following the 15 min recovery period, and did not appear to be different. It may be possible that any significantly elevated or deflated blood pressure values taken immediately following the workout returned to a normal range following the cool down.

**Possible Limitations**

During a good portion of data collection, the K4b2 Cosmed's batteries were defective. It was unknown to the investigator at what point the battery may die and need a replacement. As a result, all participants during the first month of data collection had to perform the traditional workout first. The reason the investigator decided this is because it is relatively easy to know if the battery has died and replace it while the participant is running on the treadmill. However, during the CrossFit® session while the participant is running on a track, the investigator would not be able to hear that the battery has died and subsequently be able to replace it. The investigator felt this was the best course of action until replacement batteries arrived. Once replacement batteries arrived, the investigator resumed the initial method of randomizing the order the workout sessions were performed. Unfortunately, only seven participants performed the CrossFit® workout first. It is possible that values during the first workout may be skewed due to nervousness and the discomfort associated with wearing the K4b2 Cosmed for the first time. However, from looking at the data, it is unclear if that is the case.

The CrossFit® workout lasted an average 2 min 38 sec longer than the traditional workout. As the statistics show, this time difference did not affect the results of the study. When time is taken into account (kcal/min), the CrossFit® workout still led to a greater caloric expenditure over the traditional workout.

The manner in which the treadmill run was performed may have affected the data, but it was necessary in order to perform the traditional workout in a timely manner. All participants began by walking on the treadmill at 3 mph and the speed was increased by 0.5 mph each minute until 80% of the participants HRR was achieved (±5 bpm). For some participants, the target heart rate was achieved within the first 2 min, but for some of the more aerobically fit participants, it took up to 6 min to achieve. This means that nearly all the participants spent less than the prescribed 20 min on the treadmill at 80% of their HRR, because the first several minutes were spent working up to that point. This could be better controlled in future research by starting the more aerobically fit participants at a higher speed. Still, through further investigation of the data, it seems that there was no difference in the results between individuals of different fitness levels.

Diet and fluid intake play a role in exercise performance, but it was not controlled for this study. Participants were instructed to keep a log of their food and fluid intake before the first workout session and try to mimic it for their second workout session. The primary investigator did not strictly verify this.

The majority of participants in this study were active members of a CrossFit® gym. It is possible that they were more motivated to perform better in the CrossFit® workout than the traditional workout. However, the participants who were not active in CrossFit® achieved similar results to those who were. It is unclear whether this posed a significant limitation, but more non-CrossFit® exercisers should surely be recruited for future research studies.

## Future Research

In addition to the issues that need to be addressed from the Possible Limitations section, there are several other research opportunities that can be gleaned from this study. One would be to perform a similar study but measure EPOC during the following 12, 24 or 48 hr. The CrossFit® workout had a higher short-term EPOC than the traditional workout, and it would be worth knowing if it remains elevated over an extended period. Another study worth performing would be to track individual changes in body composition, $VO_{2max}$ and resting heart rate in untrained and/or trained participants over the course of a 6 wk CrossFit® and traditional training program. It should also be noted that results between men and women were dissimilar. Men appeared to either expend more calories in CrossFit® relative to women, or fewer calories in traditional exercise. After reviewing the literature it would appear no research has been performed that tested whether men and women differ in relative energy expenditure during different modes of exercise. It would be worth researching in the future whether the results of this study are similar in both men and women.

## Implications of this Study

Based on this study, one may assume that CrossFit® is a viable exercise program for healthy individuals seeking to be physically active and expend more calories, considering that it is comparable if not superior to traditional exercise in regards to energy expenditure. If performed at least 3 days/week, it appears to satisfactorily meet the physical activity recommendations of the surgeon general, ACSM, and numerous other professionals (ACSM, 2010; Donnelly et al, 2009; Garber et al, 2011; Haskell, Lee & Pate, 2007; U.S. Department of Health and Human Services, 1996). Unfortunately, no single workout can encapsulate an entire exercise program, either for traditional exercise or CrossFit®. The high variability of workouts performed at CrossFit® gyms makes long term energy expenditure and program viability difficult to measure. This study obtained some valuable data that may be used for future research, but the author will not attempt to make general statements based on a single study. However, due to the intensity at which metcons are performed, CrossFit® cannot be recommended to populations with any cardiovascular health condition. Individuals who are at risk for heart disease should contact their physician before beginning a CrossFit® training program. Individuals with heart conditions should be careful to monitor their heart rates during the metcon portion of a CrossFit® workout to ensure that it does not reach dangerous levels. Bergeron and colleagues (2011) came to similar conclusions in a CHAMP/ACSM executive summary discussing high intensity training programs such as CrossFit® for military personnel. While they praise high intensity training programs for the unique challenges they present and the gains in fitness that result, they do recommend that individuals with health conditions first be cleared by a doctor, and that all workouts should be performed under the supervision of a trained professional (Bergeron et al, 2011). They also warn that high intensity programs carry an increased risk of injury, although no injuries were reported in this study.

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APPENDIX A

WORKOUT TEMPLATE

Name:_________________ Age (18-44):_____ Max HR:_______ 1RM Back Squat:______

Height:___________ ACSM Day Weight:_________ CrossFit® Day Weight:____________

ACSM Day (Date:___________)

-Affix Cosmed and Polar heart rate monitor and wristwatch; start stopwatch

<u>Pre-Workout</u> – Time: 0:00

-Sit 5 minutes

-Resting Heart Rate:____________

-Resting Blood Pressure:___________

<u>Workout</u> – Time:_______________

-Jog 3 minutes on treadmill at 5mph

-Quad Stretch 20 seconds each leg

-Hamstring Stretch 30 seconds

-Calf Stretch 20 seconds each leg

Back Squat:

-1 set of 10 repetitions with an empty 45 lb. barbell

-50% 1RM:____________

-3 sets of 10 repetitions @ 50% 1RM

-1 minute rest between sets

Leg Extensions:

-3 sets of 10 repetitions

-Back Squat 300+, Leg Extension 130; 200-299, 100; 100-199, 70; less than 100, 40

-1 minute rest between sets

Calf Raises:

-1 set of 20 repetitions on each leg

Treadmill:

-Set timer for 20:00

-Walk at 3 mph at 3% grade.

-Increase the speed by ½ mph every minute until the participant has reached 80% of their heart rate reserve. Adjust speed as needed to stay within 5 beats of desired heart rate.

-80% HRR:_____________

Post-Workout – Time:__________________

-Walk at 3mph for 5 minutes

-Blood Pressure_________

-Sit 10 minutes

CrossFit® Day (Date:____________)

-Affix Cosmed and Polar chest strap; start stopwatch

Pre-Workout Time: 0:00

-Sit 5 minutes

-Resting Heart Rate:____________

-Resting Blood Pressure:____________

Workout Time:_____________

-Jog 3 minutes on treadmill at 5 mph

-10 arm circles

-10 hip swings

-5 inch worms

Back Squat:

-Perform 1 set of 10 repetitions with an empty barbell

-40% 1RM:__________ 60% 1RM:___________ 75% 1RM:____________

-Perform 1 warm-up set of 8 repetitions @ 40% 1RM

-Perform 1 warm-up set of 6 repetitions @ 60% 1RM

-5 sets of 5 repetitions @ 75% 1RM

-3 minute rest between sets

Track:

-The participant will perform as many rounds as possible in 15 minutes of…

 -Run 324m

 -10 Up-and-Downs

 -15 Kettlebell Swings (25 pounds for females, 45 pounds for males)

Post-Workout Time:___________

-Walk for 5 minutes

--Blood Pressure_________

-Sit 10 minutes

# APPENDIX B

# PILOT STUDY RESULTS

Key:

1RM BS: One-rep max back squat

Pre-HR: Resting heart rate

Pre-BP: Resting blood pressure

EE: Energy expenditure during particular activity

EE/min: Average energy expenditure per minute during a particular activity

Post-HR: Heart rate following recovery period

Post-BP: Blood pressure following recovery period

Avg.: Average across the whole workout session

| | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| | Age | 32 | 23 | 34 | 23 |
| | Max HR | 188 | 197 | 186 | 197 |
| | Height | 179.7 | 169.5 | 185.5 | 170.5 |
| | 1RM BS | 310 | 250 | 280 | 265 |
| | Gender | M | F | M | M |
| | | | | | |
| ACSM | Weight | 78.8 | 66 | 81.4 | 69.8 |
| | Pre-HR | 68 | 67 | 69 | 54 |
| | Pre-BP | 115/70 | 110/60 | 140/80 | 110/65 |
| | EE Squats | 59.42 | 40.42 | 51.49 | 62.31 |
| | EE/min Squats | 7.43 | 6.74 | 7.36 | 7.79 |
| | EE Ext/Calf | 44.36 | 32.54 | 65.78 | 46.3 |
| | EE/min Ext/Calf | 7.39 | 5.42 | 8.22 | 8.42 |
| | EE Treadmill | 186.34 | 134.75 | 163.24 | 163.28 |
| | EE/min Treadmill | 9.32 | 6.74 | 8.16 | 8.16 |
| | EE Recovery | 54.81 | 31.97 | 58.51 | 67.05 |
| | EE/min Recovery | 3.65 | 2.13 | 3.9 | 4.47 |
| | EE Total | 391.24 | 276.47 | 386.84 | 386.83 |
| | Avg. EE/min | 7.56 | 5.35 | 6.99 | 7 |
| | Post-HR | 79 | 94 | 89 | 83 |

| | | | | | |
|---|---|---|---|---|---|
| | Post-BP | 120/63 | 105/65 | 125/82 | 110/65 |
| | Avg. $VO_2$/Kg | 19.56 | 15.96 | 16.48 | 16.48 |
| | Avg. METs | 5.6 | 4.56 | 4.71 | 4.71 |
| | Avg. RER | 1 | 1.04 | 1.16 | 1.16 |
| | Avg. HR | 132 | 134 | 131 | 131 |
| | HR max | 175 | 174 | 169 | 169 |
| | $VO_2$/kg max | 37.37 | 30.13 | 38.41 | 38.41 |
| | Time | 1:01:53 | 57:44:00 | 1:02 | 1:02:59 |
| | | | | | |
| Crossfit | Weight | 77.4 | 65.8 | 80.6 | 70.3 |
| | Pre-HR | 66 | 62 | 67 | 65 |
| | Pre-BP | 112/65 | 105/65 | 140/82 | 120/70 |
| | EE Squats | 127.54 | 74.93 | 127.32 | 96.19 |
| | EE/min Squats | 6.71 | 4.16 | 6.7 | 5.34 |
| | EE Metcon | 191.26 | 128.44 | 178.14 | 173.34 |
| | EE/min Metcon | 12.75 | 8.56 | 11.88 | 11.56 |
| | EE Recovery | 68.35 | 18.63 (2:00 worth) | 53.21 | 71.99 |
| | EE/min Recovery | 4.56 | N/A | 3.55 | 4.8 |
| | EE Total | 445.62 | 263.48 (missing final 13:00) | 431.09 | 391.71 |
| | Avg. EE/min | 8.89 | 6.26 | 8.21 | 7.67 |
| | Post-HR | 94 | 98 | 93 | 98 |
| | Post-BP | 120/65 | 105/65 | 122/79 | 110/70 |
| | Avg. $VO_2$/Kg | 20.74 | 18.31 | 17.54 | 20.71 |
| | Avg. METs | 5.92 | 5.23 | 5.01 | 5.92 |
| | Avg. RER | 1.31 | 1.11 | 1.58 | 1.19 |
| | Avg. HR | 146 | 147 | 137 | 146 |
| | HR max | 189 | 189 | 178 | 187 |
| | $VO_2$/kg max | 53.75 | 48.44 | 39.86 | 61.29 |
| | Time | 1:03:21 | 49:04 (missing final 13:00) | 1:02:25 | 1:03 |

APPENDIX C

PILOT STUDY TEMPLATE

Name:____________________ Age (18-44):_____ 1RM Back Squat:______

-Fill out PARQ/Waiver on first session

-No exercise day of or day before

-No caffeine for 12 hours before

-Make note of food and fluids consumed, try to make it similar next session

-Workout must be at least one week apart, same time of day

ACSM Day (Date:___________)

<u>Pre-Workout</u> – Time:____________

-Attach Cosmed and Heart Rate Monitor

-Sit 5 minutes

-Resting $VO_2$:_________

-Resting Heart Rate:____________

-Resting Blood Pressure:_____________

<u>Workout</u> – Time:_______________

-Jog 3 minutes on treadmill at 5mph

-Quad Stretch 20 seconds each leg

-Hamstring Stretch 30 seconds

-Calf Stretch 20 seconds each leg

Back Squat:

-1 set of 15 repetitions with an empty barbell

-3 sets of 10 repetitions @ 60% 1RM

-1 minute rest between sets

Leg Extensions:

-3 sets of 10 repetitions (100 pounds for females, 150 pounds for males)

-1 minute rest between sets

Calf Raises:

-1 set of 20 repetitions on each leg

Treadmill:

-Set timer for 20:00

-Run at 5 mph at 3% grade.

-Increase the speed by ½ mph every minute until either the participant has reached an RPE of 15 on the Rating of Perceived Exertion Borg RPE Scale or their heart rate reaches 75% of their max heart rate

-Particpants Max Heart Rate___________

Post-Workout – Time:__________________

-Walk at 3mph for 5 minutes

-Sit 10 minutes

-Heart Rate:_______________

-Blood Pressure:__________________

Crossfit Day (Date:____________)

Pre-Workout Time:_____________

-Attach Cosmed and Heart Rate Monitor

-Sit 5 minutes

-Resting $VO_2$:__________

-Resting Heart Rate:_____________

-Resting Blood Pressure:_____________

Workout Time:_____________

-Jog 3 minutes at 5 mph

-10 arm circles

-10 hip swings

-5 inch worms

Back Squat:

-Perform 1 set of 10 repetitions with an empty barbell

-Perform 1 set of 8 repetitions @ 40% 1RM

-Perform 1 set of 6 repetitions @ 60% 1RM

-5 sets of 5 repetitions @ 75% 1RM

-3 minute rest between sets

Hollow Holds:

-With what time remains until we reach the 30 minute mark and can begin the metabolic conditioning, the participant will perform intervals of 20 seconds in a hollow hold and 20 seconds of rest

-Intervals Performed___________

Track:

-The participant will perform as many rounds as possible in 15 minutes of…

-2 Laps

-10 Up-and-Downs

-15 Kettlebell Swings (25 pounds for females, 45 pounds for males)

Post-Workout Time:___________

-Walk for 5 minutes

-Sit 10 minutes

-Heart Rate:_________

-Blood Pressure:_____________

APPENDIX D

PAR-Q

Physical Activity Readiness Questionnaire (PAR-Q)

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

**If you answered yes to any question:**
Please consult a physician before engaging in this research study.

**If you answered no to all questions:**
You may safely participate in this research study.

# APPENDIX E

# INFORMED CONSENT

TEXAS WOMAN'S UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

Title: Caloric Expenditure During One Exercise Session Following ACSM and CrossFit® Guidelines

Investigator: Matt Brisebois ............................................................ mbrisebois@twu.edu 214/766-7275
Advisor: Kyle Biggerstaff, Ph.D. ............................................ kbiggerstaff@twu.edu 940/898-2596

Explanation and Purpose of the Research

You are being asked to participate in a research study for Mr. Brisebois' thesis at Texas Woman's University. The purpose of this study will be to determine the physiological responses to a CrossFit® and ACSM exercise and recovery sessions and analyze the difference between the caloric expenditures. You have been asked to participate in this study because you are between the ages of 18 and 44, have no health risks and are regularly physically active.

Description of Procedures

You will participate in two separate 60 minute exercise and recovery sessions, one following ACSM guidelines and the other the CrossFit® methodology. The order in which you perform the sessions will be random, and must be at least one week apart. You will complete a physical activity readiness questionnaire (PAR-Q) prior to your first session as well as obtain a 1-rep max back squat. A 1-rep max back squat is the most weight that you can squat properly while holding a barbell across your upper back. Anthropometric measurements of height and body weight will be performed in the exercise physiology laboratory in Pioneer Hall before the first session, and body weight will be measured again before the second session. You will need to avoid exercise the day of and day before each session, as well as keep a 12-hour food and fluid log before the first session so that you may replicate those conditions for the next session. You should also perform each session around the same time of day that you normally exercise. These factors have an effect on exercise performance and energy expenditure and are therefore important to replicate. A $K4b^2$ Cosmed unit will be used to collect data during the test which consists of a face mask and harness. The face mask will be securely fitted around your mouth area and the harness to your chest and back. You will also be fitted with a Polar heart rate monitor which involves a strap around your chest at the sternum and a wrist watch. The 45 minute exercise session will begin by sitting for 5 minutes so that resting values can be obtained, then you will perform a series of exercise for the remaining 40 minutes. For the CrossFit® session, you will start by performing 5 sets of 5 reps of back squats, followed by a 15 minute conditioning cycle consisting of running, kettlebell swings and up-and-downs. The ACSM session will consist of 3 sets of 10 back squats, 3 sets of 10 leg extensions, a set of 20 calf raises, and then 20 minutes on the treadmill working at a percentage of your heart rate reserve. Working at a percentage of your heart rate reserve ensures that you are working at comfortable intensity relative to your fitness level. The recovery session immediately follows the exercise session and involves 5 minutes of walking then 10 minutes of sitting, as well as obtaining your blood pressure with the use of an arm cuff and sphygmomanometer. If at any point you feel pain or severe discomfort or fatigue, you will be allowed to stop. When the session is finished, the $K4b^2$ Cosmed and Polar heart rate monitor will be removed. The total time commitment will be approximately 3.5 hours.

Potential Risks

You will be exposed to the following potential risks.

Risk of loss of Confidentiality – to minimize this risk, all data collected will be coded and your name will not be used. There is a potential risk of loss of confidentiality in all email, downloading, and internet transactions.

The primary investigator will keep all information in a password protected computer that only the primary investigator has access to. All testing information will be treated as privileged and confidential. TWU students, faculty, and Startup program members may be present during each session; therefore, loss of confidentiality will occur. The principal investigator will avoid saying your name, releasing any of your data or pointing you out during each session. Confidentiality will be protected to the extent that is allowed by law.

Risk of embarrassment – to minimize this risk, the anthropometric measurements will be performed in a closed room in the exercise laboratory in Pioneer Hall with only the participant and the primary investigator. The primary investigator will not draw attention to you during either session.

Risk of injury or physical discomfort – performing any exercise can cause discomfort or injury. To avoid this, an adequate warm-up and cool-down will be performed. The primary investigator will also provide instruction on how to perform each exercise safely. The intensity of exercise will also be controlled based on your one-rep max back squat, gender, and resting and max heart rates.

Risk of fatigue – the intensity and rest periods are specifically measured, so there is a risk of fatigue. In the case of very uncomfortable or severe fatigue, you will be allowed to rest.

Risk of loss of time – all procedures will be executed as efficiently as possible. The primary investigator will be available to assist during both sessions. You are allowed to withdraw at any time.

Risk of loss of anonymity – TWU students, faculty, and Startup program members may be present during each session; therefore, loss of anonymity will occur. The primary investigator will avoid saying your name or drawing attention to you during both sessions.

Risk of muscle soreness - both sessions will consist of an adequate warm-up and cool-down to minimize or avoid this risk. Intensity will also be controlled based on your one-rep max back squat, gender and resting and max heart rates.

Coercion – your participation in this study is strictly voluntary.

The Researchers will try to prevent any problem that could happen because of this research. You should let the researchers know at once if there is a problem and they will help you. However, TWU does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

Participation and Benefits

Your participation in this study is completely voluntary. Should you decide to participate in the research, you are allowed to withdraw from the study without penalty. The amount of kilocalories you expending during each session will be available upon request. *

Questions Regarding the Study

You will be given a copy of this signed and dated consent form to keep. If you have any questions about the research study you should ask the researchers; their phone numbers are at the top of this form. If you have questions about your rights as a participant in this research or the way this study has been conducted, you may contact the Texas Woman's University Office of Research and Sponsored Programs at 940-898-3378 or via e-mail at IRB@twu.edu.

______________________________________________________     _______________
Signature of Participant                                                                                    Date

*If you would like to know the results of this study tell us where you want them to be sent:
Email: __________________________
or
Address:
__________________________________

___________________________________

APPENDIX F

DATA

Key:

XFIT: Denotes values recorded from the CrossFit® workout

ACSM: Denotes values recorded from the traditional workout

1RM BS: 1-rep max back squat

XFIT/ACSM Time: Total time to complete the workout and recovery sessions

EE: Energy Expenditure

EE/min: Energy Expenditure per minute

Warmup: Denotes the warmup portion of the respective workout

Lifting: Denotes the weightlifting portion of the respective workout

Metcon: Denotes the metcon/circuit training portion of the CrossFit® workout

Treadmill: Denotes the 20 min treadmill run in the traditional workout

Recovery: Denotes the 15 min recovery portion of the respective workout

HR: Heart Rate

MAP: Mean Arterial Blood Pressure

BP: Blood Pressure (systolic/diastolic)

Max: Indicates the maximum value achieved during the workout

Pre: Indicates values obtained during the 5 min sit at the beginning of the workout

Post: Indicates values obtained immediately following the metcon or treadmill run

M: Male

F: Female

Demographic Data

| Sex | Participant | Age (yrs) | Height (cm) | Weight XFIT (kg) | Weight ACSM (kg) | 1RM BS (kg) |
|---|---|---|---|---|---|---|
| F | 1 | 20 | 167 | 59 | 59 | 52.16 |
| | 2 | 28 | 167 | 62 | 61 | 43.09 |
| | 3 | 27 | 169 | 56 | 56 | 70.31 |
| | 4 | 31 | 158 | 62 | 61 | 65.77 |
| | 5 | 19 | 166 | 59 | 58 | 79.38 |
| | 6 | 23 | 157 | 54 | 54 | 83.91 |
| | 7 | 23 | 157 | 57 | 57 | 83.91 |
| | 8 | 25 | 157 | 61 | 61 | 70.31 |
| | 9 | 24 | 172 | 76 | 76 | 92.99 |
| | 10 | 29 | 162 | 63 | 62 | 79.38 |
| | 11 | 27 | 154 | 50 | 51 | 83.91 |
| | 12 | 36 | 158 | 63 | 65 | 108.86 |
| | 13 | 25 | 164 | 68 | 68 | 61.24 |
| | 14 | 27 | 161 | 57 | 58 | 68.04 |
| | 15 | 32 | 168 | 71 | 70 | 61.24 |
| | Mean | 26 | 162 | 61 | 61 | 73.63 |
| | Std. Dev. | 5 | 6 | 6 | 6 | 16.51 |
| M | | | | | | |
| | 16 | 32 | 160 | 78 | 79 | 129.27 |
| | 17 | 31 | 174 | 81 | 81 | 108.86 |
| | 18 | 44 | 190 | 99 | 100 | 142.88 |
| | 19 | 32 | 181 | 102 | 101 | 129.27 |
| | 20 | 20 | 181 | 80 | 81 | 124.74 |
| | 21 | 28 | 182 | 88 | 89 | 163.29 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 22 | 27 | 172 | 72 | 71 | 97.52 |
| | 23 | 37 | 169 | 78 | 78 | 111.13 |
| | 24 | 37 | 177 | 88 | 88 | 156.49 |
| | 25 | 20 | 176 | 89 | 88 | 165.56 |
| | 26 | 22 | 171 | 80 | 79 | 52.16 |
| | 27 | 33 | 178 | 82 | 82 | 136.08 |
| | 28 | 24 | 169 | 74 | 73 | 129.27 |
| | 29 | 31 | 179 | 118 | 118 | 149.69 |
| | 30 | 33 | 172 | 83 | 83 | 97.52 |
| Mean | | 30 | 175 | 86 | 86 | 126.25 |
| Std. Dev. | | 7 | 7 | 12 | 12 | 29.83 |
| | | | | | | |
| Combined Mean | | 28 | 169 | 74 | 74 | 99.94 |
| Combined Std. Dev. | | 6 | 9 | 16 | 16 | 35.74 |

Maximum Heart Rates, Pre- and Post-Mean Arterial Blood Pressure and Changes in Mean Arterial Blood Pressure from pre- to post-workout

| Sex | Participant | | Age-Predicted Max HR (bpm) | Max HR XFIT (bpm) | Max HR ACSM (bpm) | Pre-MAP XFIT (mmHg) | Post-MAP XFIT (mmHg) | Pre-MAP ACSM (mmHg) | Post-MAP ACSM (mmHg) | MAP Change XFIT (mmHg) | MAP Change ACSM (mmHg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F | | 1 | 194 | 191 | 178 | 77.3 | 84.7 | 79.3 | 74 | 7.4 | -5.3 |
| | | 2 | 188 | 199 | 175 | 72.7 | 90 | 77.3 | 76 | 17.3 | -1.3 |
| | | 3 | 189 | 186 | 172 | 82.7 | 91.3 | 84.7 | 84 | 8.6 | -0.7 |
| | | 4 | 186 | 197 | 164 | 72 | 89.3 | 82 | 85.3 | 17.3 | 3.3 |
| | | 5 | 194 | 208 | 181 | 90 | 86.7 | 98 | 93.3 | -3.3 | -4.7 |
| | | 6 | 191 | 206 | 177 | 85.3 | 90.7 | 83.3 | 87.3 | 5.4 | 4 |
| | | 7 | 191 | N/A | N/A | 90.7 | 98 | 84.7 | 86 | 7.3 | 1.3 |
| | | 8 | 190 | N/A | N/A | 92.7 | 80.7 | 86 | 76.7 | -12 | -9.3 |
| | | 9 | 191 | 187 | 170 | 82 | 94 | 85.3 | 83.3 | 12 | -2 |
| | | 10 | 187 | 186 | 172 | 77.3 | 83.3 | 87.3 | 82 | 6 | -5.3 |
| | | 11 | 189 | 181 | 168 | 87.3 | 92.7 | 78 | 82.7 | 5.4 | 4.7 |
| | | 12 | 183 | 183 | 178 | 90.7 | 87.3 | 102 | 82 | -3.4 | -20 |
| | | 13 | 190 | 195 | 175 | 86.7 | 104.7 | 90 | 96.7 | 18 | 6.7 |
| | | 14 | 189 | N/A | N/A | 88.7 | 80.7 | 97.3 | 97.3 | -8 | 0 |
| | | 15 | 185 | 189 | 168 | 82 | 80.7 | 79.3 | 82 | -1.3 | 2.7 |
| | Mean | | 189 | 192 | 173 | 83.9 | 89 | 86.3 | 84.6 | 5.1 | -1.7 |
| | Std. Dev. | | 3 | 8 | 5 | 6.6 | 6.8 | 7.6 | 6.9 | 9.2 | 6.7 |
| M | | | | | | | | | | | |
| | | 16 | 185 | 176 | 164 | 94 | 98 | 93.3 | 96.7 | 4 | 3.4 |
| | | 17 | 186 | 184 | 167 | 87.3 | 84 | 98 | 92.7 | -3.3 | -5.3 |
| | | 18 | 177 | 185 | 160 | 97.3 | 108 | 91.3 | 102 | 10.7 | 10.7 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 185 | 195 | 172 | 82.7 | 78 | 92.7 | 97.3 | -4.7 | 4.6 |
| 20 | 194 | 182 | 176 | 88 | 82.7 | 114 | 98.7 | -5.3 | -15.3 |
| 21 | 188 | 184 | 162 | 87.3 | 102 | 89.3 | 98.7 | 14.7 | 9.4 |
| 22 | 189 | 192 | 180 | 84 | 86 | 93.3 | 93.3 | 2 | 0 |
| 23 | 182 | 187 | 167 | 101.3 | 94 | 103.3 | 99.3 | -7.3 | -4 |
| 24 | 182 | 185 | 162 | 97.3 | 118.7 | 96 | 102 | 21.4 | 6 |
| 25 | 194 | 198 | 174 | 95.3 | 104.7 | 94 | 101.3 | 9.4 | -3.3 |
| 26 | 192 | 198 | 194 | 100 | 93.3 | 106.7 | 95.3 | -6.7 | -11.4 |
| 27 | 185 | 187 | 167 | 84.7 | 92 | 95.3 | 84 | 7.3 | -11.3 |
| 28 | 191 | 179 | 173 | 91.3 | 82.7 | 90 | 95.3 | -8.6 | 5.3 |
| 29 | 186 | 177 | 166 | 105.3 | 90.7 | 99.3 | 90.7 | -14.6 | -8.6 |
| 30 | 185 | 193 | 186 | 92.7 | 91.3 | 83.3 | 85.3 | -1.4 | 2 |
| Mean | 187 | 187 | 171 | 92.6 | 93.7 | 96 | 95.5 | 1.2 | -1.2 |
| Std. Dev. | 5 | 7 | 10 | 6.9 | 11 | 7.6 | 5.5 | 9.9 | 8 |
| | | | | | | | | | |
| Combined Mean | 188 | 189 | 172 | 88.2 | 91.4 | 91.1 | 90 | 3.1 | -1.5 |
| Combined Std. Dev. | 4 | 8 | 8 | 8 | 9.3 | 8.9 | 8.3 | 9.6 | 7.3 |

Energy Expenditure per section of each workout

| Sex | Participant | | EE Warmup XFIT (kcal) | EE Warmup ACSM (kcal) | EE Lifting XFIT (kcal) | EE Lifting ACSM (kcal) | EE Metcon (kcal) | EE Treadmill (kcal) | EE Recovery XFIT (kcal) | EE Recovery ACSM (kcal) |
|---|---|---|---|---|---|---|---|---|---|---|
| F | | 1 | 46.1 | 40.3 | 96.8 | 75.9 | 157.5 | 199 | 46.3 | 45.6 |
| | | 2 | 39.5 | 40.8 | 87 | 67.2 | 160.8 | 189.7 | 45.4 | 40.4 |
| | | 3 | 41.3 | 44.1 | 93.3 | 57.5 | 162 | 186.1 | 40.8 | 39.4 |
| | | 4 | 45.6 | 40.4 | 103 | 76.2 | 199.1 | 198.2 | 58.7 | 44.2 |
| | | 5 | 37.5 | 35 | 113.7 | 67.9 | 192.6 | 187.6 | 52.3 | 43.7 |
| | | 6 | 42 | 43.2 | 116.3 | 84.7 | 168.6 | 184.1 | 53.3 | 42.3 |
| | | 7 | 51.5 | 45.5 | 103.3 | 86.1 | 173.1 | 206.1 | 58.1 | 52 |
| | | 8 | 45 | 43.9 | 88.2 | 70 | 145.6 | 178.3 | 46.9 | 50.3 |
| | | 9 | 57.1 | 49.2 | 114 | 77.5 | 205.9 | 244.8 | 64.6 | 59 |
| | | 10 | 46.1 | 37.7 | 112.3 | 78.2 | 174.5 | 203.1 | 49.3 | 39.5 |
| | | 11 | 40.1 | 35.4 | 94.5 | 67.7 | 171.8 | 199.6 | 52.6 | 47.9 |
| | | 12 | 48 | 34.9 | 100.4 | 66.8 | 188.1 | 224 | 49.4 | 45.6 |
| | | 13 | 48 | 41.7 | 82.2 | 68.6 | 169 | 183.3 | 48.4 | 45.9 |
| | | 14 | 47.2 | 44.2 | 113.1 | 85.6 | 172.4 | 157.7 | 55.8 | 46.1 |
| | | 15 | 46.7 | 46.8 | 107.6 | 78.1 | 189.5 | 189 | 37.8 | 46.2 |
| | Mean | | 45.4 | 41.5 | 101.7 | 73.9 | 175.4 | 195.4 | 50.6 | 45.9 |
| | Std. Dev. | | 5 | 4.4 | 11.1 | 8.2 | 16.6 | 20.1 | 7 | 5.1 |
| M | | | | | | | | | | |
| | | 16 | 71.9 | 51 | 142.4 | 105.4 | 235.2 | 262.8 | 69.8 | 60.4 |
| | | 17 | 58.4 | 48.5 | 132 | 90.9 | 212.6 | 255 | 56.4 | 59.2 |
| | | 18 | 70.6 | 60.1 | 186.5 | 126.5 | 289.2 | 297.2 | 96.8 | 72.3 |
| | | 19 | 72.1 | 66.5 | 180.3 | 140.9 | 248.1 | 258.7 | 73 | 69.1 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 20 | 67.1 | 60.4 | 183.9 | 88.4 | 240.9 | 270.1 | 69.5 | 62.6 |
| 21 | 71.4 | 60.7 | 185.3 | 123.3 | 295.9 | 343.9 | 94.6 | 81.6 |
| 22 | 47.7 | 52.2 | 145.6 | 83.4 | 221.7 | 222 | 43.9 | 43.4 |
| 23 | 77.8 | 65.2 | 170.3 | 125.2 | 246.6 | 268.6 | 84.4 | 73.8 |
| 24 | 70.4 | 61.8 | 172.9 | 118 | 303 | 320.9 | 91.7 | 65.8 |
| 25 | 71.6 | 68.4 | 202.2 | 132.6 | 311.4 | 334.2 | 91.3 | 72.2 |
| 26 | 53.9 | 52.1 | 122.6 | 101.4 | 184.4 | 164.3 | 52.7 | 52.8 |
| 27 | 69.2 | 65.8 | 172.6 | 115.5 | 275.4 | 315.2 | 79 | 77.8 |
| 28 | 52.8 | 39 | 144.4 | 77.1 | 242.9 | 234 | 65.3 | 52.3 |
| 29 | 80.4 | 71.3 | 226.1 | 126 | 302 | 319.8 | 84.3 | 72.1 |
| 30 | 52.3 | 61 | 176.7 | 111.8 | 194.7 | 185.7 | 61.4 | 53.3 |
| Mean | 65.8 | 58.9 | 169.6 | 111.1 | 253.6 | 270.2 | 74.3 | 64.6 |
| Std. Dev. | 10.1 | 8.7 | 27.7 | 19.3 | 40.8 | 53.3 | 16.3 | 10.9 |
| | | | | | | | | |
| Combined Mean | 55.6 | 50.2 | 135.7 | 92.5 | 214.5 | 232.8 | 62.5 | 55.2 |
| Combined Std. Dev. | 13 | 11.1 | 40.3 | 23.9 | 50.2 | 54.9 | 17.2 | 12.7 |

Total Energy Expenditure, Total Workout and Recovery Time and Energy Expenditure per Minute

| Sex | Participant | | EE XFIT (kcal) | EE ACSM (kcal) | XFIT Time (min) | ACSM Time (min) | EE/Min XFIT (kcal/min) | EE/min ACSM (kcal/min) |
|---|---|---|---|---|---|---|---|---|
| F | | 1 | 346.7 | 360.7 | 61.72 | 61.87 | 5.6 | 5.8 |
| | | 2 | 332.6 | 338.2 | 63.58 | 60.1 | 5.2 | 5.6 |
| | | 3 | 337.3 | 327.1 | 61.43 | 57.95 | 5.5 | 5.6 |
| | | 4 | 406.3 | 359 | 63.25 | 59.5 | 6.4 | 6 |
| | | 5 | 396 | 334.2 | 61.93 | 58.33 | 6.4 | 5.7 |
| | | 6 | 380.1 | 354.2 | 62.7 | 61.85 | 6.1 | 5.7 |
| | | 7 | 386.1 | 389.7 | 60.52 | 60.87 | 6.4 | 6.4 |
| | | 8 | 325.6 | 342.5 | 60.87 | 61.5 | 5.4 | 5.6 |
| | | 9 | 441.6 | 430.4 | 60.22 | 57.83 | 7.3 | 7.4 |
| | | 10 | 382.2 | 358.5 | 61.87 | 59.53 | 6.2 | 6 |
| | | 11 | 359.1 | 350.6 | 61.05 | 59.5 | 5.9 | 5.9 |
| | | 12 | 385.9 | 371.4 | 61.33 | 59.4 | 6.3 | 6.3 |
| | | 13 | 347.5 | 339.5 | 61.25 | 59.45 | 5.7 | 5.7 |
| | | 14 | 388.6 | 333.6 | 63.1 | 62.27 | 6.2 | 5.4 |
| | | 15 | 381.6 | 360.1 | 61.83 | 57.58 | 6.2 | 6.3 |
| | Mean | | 373.2 | 356.6 | 61.78 | 59.84 | 6.1 | 6 |
| | Std. Dev. | | 31.4 | 26.1 | 1 | 1.55 | 0.5 | 0.5 |
| M | | | | | | | | |
| | | 16 | 519.3 | 479.6 | 63.33 | 60.13 | 8.2 | 8 |
| | | 17 | 459.4 | 454.1 | 63.6 | 59.75 | 7.2 | 7.6 |
| | | 18 | 643.1 | 556.2 | 61.58 | 58.53 | 10.4 | 9.5 |
| | | 19 | 573.6 | 534.3 | 63.62 | 60.07 | 9 | 8.9 |
| | | 20 | 561.3 | 481.5 | 61.73 | 56.42 | 9.1 | 8.8 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 21 | 647.2 | 609.5 | 63.75 | 59.75 | 10.2 | 10.2 |
| | 22 | 458.9 | 400.9 | 62.58 | 59.2 | 7.3 | 6.8 |
| | 23 | 579.1 | 532.8 | 62.7 | 59.7 | 9.2 | 8.9 |
| | 24 | 638 | 566.5 | 59.92 | 59.05 | 10.7 | 9.6 |
| | 25 | 676.5 | 607.5 | 62 | 59.42 | 10.9 | 10.2 |
| | 26 | 413.6 | 370.6 | 60.95 | 58.75 | 6.8 | 6.3 |
| | 27 | 596.3 | 574.5 | 62.62 | 58.95 | 9.5 | 9.7 |
| | 28 | 505.4 | 402.3 | 61.67 | 57.03 | 8.2 | 7.1 |
| | 29 | 692.8 | 589.2 | 63.18 | 59.12 | 11 | 10 |
| | 30 | 485.1 | 411.8 | 65.22 | 62.5 | 7.4 | 6.6 |
| Mean | | 563.3 | 504.8 | 62.56 | 59.22 | 9 | 8.5 |
| Std. Dev. | | 86.8 | 81.6 | 1.31 | 1.38 | 1.4 | 1.4 |
| | | | | | | | |
| Combined Mean | | 468.2 | 430.7 | 62.2 | 59.53 | 7.5 | 7.3 |
| Combined Std. Dev. | | 116.1 | 96 | 1.21 | 1.47 | 1.8 | 1.7 |

Pre- and Post-Blood Pressure Values and Peak $VO_2$'s

| Sex | Participant | | Pre-BP ACSM (mmHg) | Post-BP ACSM (mmHg) | Pre-BP XFIT (mmHg) | Post-BP XFIT (mmHg) | Peak VO2 ACSM (L/min) | Peak VO2 XFIT (L/min) |
|---|---|---|---|---|---|---|---|---|
| F | | 1 | 106/66 | 110/56 | 100/66 | 130/62 | 2.39 | 2.38 |
| | | 2 | 108/62 | 112/58 | 102/58 | 150/60 | 2.38 | 2.67 |
| | | 3 | 110/72 | 136/58 | 108/70 | 158/58 | 2.21 | 2.3 |
| | | 4 | 110/68 | 120/68 | 100/58 | 124/72 | 2.3 | 3 |
| | | 5 | 118/88 | 124/78 | 110/80 | 120/70 | 2.19 | 2.9 |
| | | 6 | 110/70 | 130/66 | 108/74 | 148/62 | 2.14 | 2.52 |
| | | 7 | 106/74 | 122/68 | 112/80 | 158/68 | 2.39 | 2.69 |
| | | 8 | 118/70 | 126/52 | 122/78 | 130/56 | 2.25 | 2.3 |
| | | 9 | 112/72 | 130/60 | 110/68 | 162/60 | 2.92 | 3.19 |
| | | 10 | 114/74 | 122/62 | 108/62 | 130/60 | 2.34 | 2.6 |
| | | 11 | 102/66 | 128/60 | 126/68 | 158/60 | 2.49 | 2.56 |
| | | 12 | 130/88 | 110/68 | 112/80 | 138/62 | 2.64 | 2.77 |
| | | 13 | 110/80 | 130/80 | 108/76 | 146/84 | 2.3 | 2.5 |
| | | 14 | 128/82 | 140/76 | 110/78 | 122/60 | 2.11 | 2.51 |
| | | 15 | 102/68 | 110/68 | 110/68 | 122/60 | 2.38 | 2.9 |
| | Mean | | 112/73 | 123/65 | 110/71 | 140/64 | 2.36 | 2.65 |
| | Std. Dev. | | *8/8 | *10/8 | *7/8 | *15/7 | 0.21 | 0.26 |
| M | | | | | | | | |
| | | 16 | 120/80 | 150/70 | 122/80 | 170/62 | 3.4 | 3.64 |
| | | 17 | 126/84 | 150/64 | 110/76 | 136/58 | 3.12 | 3.27 |
| | | 18 | 110/82 | 150/78 | 116/88 | 172/76 | 3.56 | 4.35 |
| | | 19 | 118/80 | 140/76 | 120/64 | 130/52 | 3.06 | 3.72 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 20 | 150/96 | 140/78 | 120/72 | 124/62 | 3.05 | 3.71 |
| 21 | 108/80 | 168/64 | 118/72 | 170/68 | 4.17 | 4.4 |
| 22 | 116/82 | 120/80 | 108/72 | 122/68 | 2.54 | 3.24 |
| 23 | 142/84 | 170/64 | 152/76 | 170/56 | 3.12 | 3.67 |
| 24 | 124/82 | 150/78 | 128/82 | 220/68 | 3.83 | 4.47 |
| 25 | 142/70 | 160/72 | 150/68 | 190/62 | 4.04 | 4.56 |
| 26 | 136/92 | 122/82 | 120/90 | 140/70 | 2.33 | 2.74 |
| 27 | 126/80 | 136/58 | 130/62 | 164/56 | 3.78 | 3.97 |
| 28 | 110/80 | 130/78 | 114/80 | 124/62 | 2.58 | 3.53 |
| 29 | 126/86 | 128/72 | 140/88 | 136/68 | 3.83 | 4.61 |
| 30 | 110/70 | 120/68 | 118/80 | 138/68 | 2.5 | 3.07 |
| Mean | 124/82 | 142/72 | 136/76 | 154/64 | 3.26 | 3.8 |
| Std. Dev. | *13/7 | *16/7 | *16/8 | *28/6 | 0.6 | 0.58 |
| | | | | | | |
| Combined Mean | 118/78 | 133/69 | 117/74 | 147/64 | 2.81 | 3.22 |
| Combined Std. Dev. | *12/8 | *16/8 | *13/9 | *24/7 | 0.63 | 0.73 |

Average $VO_2$ During Each Workout Session

| Sex | Participant | | Avg $VO_2$ XFIT (L/min) | Avg $VO_2$ Trad (L/min) |
|---|---|---|---|---|
| F | | 1 | 1.16 | 1.2 |
| | | 2 | 1.07 | 1.18 |
| | | 3 | 1.09 | 1.16 |
| | | 4 | 1.29 | 1.22 |
| | | 5 | 1.32 | 1.18 |
| | | 6 | 1.25 | 1.2 |
| | | 7 | 1.3 | 1.34 |
| | | 8 | 1.09 | 1.17 |
| | | 9 | 1.5 | 1.54 |
| | | 10 | 1.27 | 1.24 |
| | | 11 | 1.2 | 1.18 |
| | | 12 | 1.28 | 1.26 |
| | | 13 | 1.16 | 1.19 |
| | | 14 | 1.24 | 1.08 |
| | | 15 | 1.26 | 1.29 |
| | Mean | | 1.23 | 1.23 |
| | Std. Dev. | | 0.11 | 0.11 |
| M | | 16 | 1.69 | 1.71 |
| | | 17 | 1.47 | 1.59 |
| | | 18 | 2.14 | 1.97 |
| | | 19 | 1.81 | 1.85 |

| | | | |
|---|---|---|---|
| | 20 | 1.84 | 1.69 |
| | 21 | 2.06 | 2.1 |
| | 22 | 1.56 | 1.38 |
| | 23 | 1.91 | 1.86 |
| | 24 | 2.17 | 1.97 |
| | 25 | 2.19 | 2.1 |
| | 26 | 1.36 | 1.27 |
| | 27 | 1.95 | 1.99 |
| | 28 | 1.65 | 1.32 |
| | 29 | 2.19 | 1.97 |
| | 30 | 1.48 | 1.27 |
| Mean | | 1.83 | 1.74 |
| Std. Dev. | | 0.29 | 0.3 |
| | | | |
| Combined Mean | | 1.53 | 1.48 |
| Combined Std. Dev. | | 0.37 | 0.34 |

15 Min Recovery $VO_2$ (L/min)

| | | Minute | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Participant | Workout | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1 | CrossFit | 1.58 | 1.18 | 1.16 | 1.09 | 1.04 | 0.69 | 0.38 | 0.43 | 0.4 | 0.33 | 0.38 | 0.31 | 0.33 | 0.32 | 0.36 |
| | Traditional | 1.72 | 1.29 | 1.01 | 1.04 | 1.13 | 0.76 | 0.4 | 0.33 | 0.31 | 0.48 | 0.23 | 0.3 | 0.33 | 0.27 | 0.37 |
| 2 | CrossFit | 1.43 | 1 | 0.97 | 0.91 | 0.94 | 0.77 | 0.84 | 0.59 | 0.34 | 0.35 | 0.33 | 0.28 | 0.25 | 0.25 | 0.3 |
| | Traditional | 1.4 | 0.98 | 0.88 | 0.93 | 0.84 | 0.6 | 0.46 | 0.44 | 0.39 | 0.32 | 0.39 | 0.32 | 0.3 | 0.26 | 0.31 |
| 3 | CrossFit | 1.84 | 0.95 | 0.85 | 0.82 | 0.76 | 0.56 | 0.36 | 0.3 | 0.33 | 0.31 | 0.26 | 0.3 | 0.24 | 0.17 | 0.19 |
| | Traditional | 1.64 | 1.02 | 0.88 | 0.79 | 0.69 | 0.66 | 0.39 | 0.26 | 0.34 | 0.27 | 0.22 | 0.3 | 0.27 | 0.21 | 0.24 |
| 4 | CrossFit | 1.98 | 1.32 | 1.29 | 1.16 | 1.13 | 0.95 | 0.6 | 0.53 | 0.52 | 0.49 | 0.46 | 0.45 | 0.43 | 0.43 | 0.36 |
| | Traditional | 1.61 | 1.14 | 0.94 | 0.89 | 1.05 | 0.65 | 0.44 | 0.36 | 0.35 | 0.32 | 0.27 | 0.32 | 0.35 | 0.29 | 0.27 |
| 5 | CrossFit | 1.71 | 1.37 | 1.26 | 1.05 | 1.17 | 0.97 | 0.59 | 0.48 | 0.47 | 0.36 | 0.37 | 0.41 | 0.37 | 0.32 | 0.33 |
| | Traditional | 1.56 | 1.09 | 0.9 | 0.88 | 0.93 | 0.66 | 0.47 | 0.38 | 0.42 | 0.34 | 0.43 | 0.36 | 0.45 | 0.4 | 0.39 |
| 6 | CrossFit | 1.91 | 1.29 | 1.25 | 1.15 | 1.1 | 0.93 | 0.61 | 0.42 | 0.39 | 0.39 | 0.36 | 0.37 | 0.33 | 0.37 | 0.37 |
| | Traditional | 1.57 | 1.09 | 1.01 | 0.93 | 0.96 | 0.63 | 0.4 | 0.32 | 0.37 | 0.36 | 0.34 | 0.31 | 0.31 | 0.29 | 0.32 |
| 7 | CrossFit | 1.91 | 1.27 | 1.34 | 1.18 | 1.12 | 1.13 | 1.02 | 0.54 | 0.52 | 0.5 | 0.5 | 0.42 | 0.41 | 0.38 | 0.35 |
| | Traditional | 1.94 | 1.4 | 1.13 | 1.08 | 1.08 | 0.83 | 0.55 | 0.38 | 0.44 | 0.4 | 0.51 | 0.36 | 0.45 | 0.32 | 0.43 |
| 8 | CrossFit | 1.54 | 0.96 | 1.05 | 1.15 | 1.06 | 0.89 | 0.49 | 0.44 | 0.34 | 0.36 | 0.32 | 0.31 | 0.39 | 0.37 | 0.34 |
| | Traditional | 1.89 | 1.4 | 1.15 | 1.04 | 1.04 | 0.89 | 0.58 | 0.44 | 0.36 | 0.35 | 0.27 | 0.28 | 0.34 | 0.27 | 0.33 |
| 9 | CrossFit | 2.42 | 1.59 | 1.47 | 1.31 | 1.3 | 0.96 | 0.7 | 0.52 | 0.5 | 0.46 | 0.43 | 0.43 | 0.47 | 0.46 | 0.42 |
| | Traditional | 2.25 | 1.62 | 1.43 | 1.28 | 1.3 | 0.98 | 0.57 | 0.41 | 0.42 | 0.4 | 0.59 | 0.39 | 0.51 | 0.37 | 0.4 |
| 10 | CrossFit | 1.87 | 0.97 | 1.05 | 1.05 | 1 | 0.84 | 0.72 | 0.46 | 0.38 | 0.33 | 0.33 | 0.34 | 0.37 | 0.25 | 0.36 |
| | Traditional | 1.59 | 1.2 | 1.02 | 1 | 0.94 | 0.62 | 0.28 | 0.4 | 0.23 | 0.22 | 0.2 | 0.21 | 0.18 | 0.19 | 0.2 |
| 11 | CrossFit | 2.01 | 1.24 | 1.17 | 1.07 | 1.02 | 0.77 | 0.61 | 0.48 | 0.41 | 0.39 | 0.46 | 0.38 | 0.4 | 0.32 | 0.34 |
| | Traditional | 1.88 | 1.26 | 1.03 | 0.91 | 0.86 | 0.65 | 0.44 | 0.31 | 0.37 | 0.38 | 0.31 | 0.27 | 0.28 | 0.28 | 0.45 |
| 12 | CrossFit | 1.83 | 1.35 | 1.16 | 1.09 | 1.03 | 0.9 | 0.55 | 0.32 | 0.29 | 0.36 | 0.31 | 0.26 | 0.24 | 0.27 | 0.33 |
| | Traditional | 1.95 | 1.24 | 1.03 | 0.98 | 0.83 | 0.77 | 0.32 | 0.41 | 0.3 | 0.25 | 0.35 | 0.13 | 0.24 | 0.41 | 0.25 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | CrossFit | 1.57 | 1.24 | 1.25 | 1.09 | 1.08 | 0.97 | 0.7 | 0.44 | 0.25 | 0.29 | 0.26 | 0.23 | 0.21 | 0.24 | 0.22 |
| | Traditional | 1.64 | 1.29 | 1.15 | 1.24 | 1.1 | 0.72 | 0.38 | 0.32 | 0.31 | 0.29 | 0.28 | 0.31 | 0.25 | 0.23 | 0.25 |
| 14 | CrossFit | 1.91 | 1.31 | 1.15 | 1.15 | 1.14 | 0.95 | 0.55 | 0.48 | 0.6 | 0.58 | 0.57 | 0.48 | 0.38 | 0.37 | 0.4 |
| | Traditional | 1.44 | 1.2 | 1.02 | 1.04 | 1.01 | 0.84 | 0.7 | 0.35 | 0.37 | 0.39 | 0.62 | 0.18 | 0.4 | 0.32 | 0.31 |
| 15 | CrossFit | 1.18 | 1.07 | 1 | 0.96 | 0.85 | 0.44 | 0.27 | 0.35 | 0.25 | 0.25 | 0.3 | 0.26 | 0.23 | 0.19 | 0.2 |
| | Traditional | 1.62 | 1.22 | 1.26 | 1.18 | 1.11 | 0.67 | 0.37 | 0.3 | 0.35 | 0.22 | 0.27 | 0.37 | 0.24 | 0.26 | 0.25 |
| Average F | CrossFit | 1.78 | 1.21 | 1.16 | 1.08 | 1.05 | 0.85 | 0.6 | 0.45 | 0.4 | 0.38 | 0.38 | 0.35 | 0.34 | 0.31 | 0.32 |
| | Traditional | 1.71 | 1.23 | 1.06 | 1.01 | 0.99 | 0.73 | 0.45 | 0.36 | 0.36 | 0.33 | 0.35 | 0.29 | 0.33 | 0.29 | 0.32 |
| Std. Dev. F | CrossFit | 0.29 | 0.18 | 0.16 | 0.12 | 0.13 | 0.18 | 0.19 | 0.08 | 0.1 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 | 0.07 |
| | Traditional | 0.23 | 0.16 | 0.15 | 0.14 | 0.15 | 0.11 | 0.11 | 0.05 | 0.05 | 0.07 | 0.13 | 0.07 | 0.09 | 0.06 | 0.08 |
| | | | | | | | | | | | | | | | | |
| 16 | CrossFit | 2.61 | 1.6 | 1.43 | 1.44 | 1.35 | 1.19 | 1.02 | 0.75 | 0.62 | 0.6 | 0.65 | 0.54 | 0.52 | 0.51 | 0.49 |
| | Traditional | 2.62 | 1.66 | 1.4 | 1.39 | 1.37 | 0.94 | 0.45 | 0.45 | 0.39 | 0.42 | 0.4 | 0.38 | 0.4 | 0.39 | 0.41 |
| 17 | CrossFit | 1.79 | 1.35 | 1.33 | 1.25 | 1.19 | 0.82 | 0.51 | 0.53 | 0.4 | 0.4 | 0.34 | 0.4 | 0.46 | 0.41 | 0.36 |
| | Traditional | 2.41 | 1.65 | 1.35 | 1.17 | 1.23 | 0.85 | 0.73 | 0.39 | 0.44 | 0.4 | 0.31 | 0.48 | 0.45 | 0.29 | 0.42 |
| 18 | CrossFit | 3.42 | 2.18 | 2.02 | 1.82 | 1.96 | 1.76 | 1.01 | 0.77 | 0.8 | 0.65 | 0.72 | 0.69 | 0.63 | 0.57 | 0.75 |
| | Traditional | 2.62 | 2 | 1.6 | 1.52 | 1.57 | 1.16 | 0.68 | 0.59 | 0.52 | 0.63 | 0.48 | 0.48 | 0.55 | 0.5 | 0.3 |
| 19 | CrossFit | 2.55 | 1.72 | 1.69 | 1.59 | 1.55 | 1.09 | 0.87 | 0.62 | 0.61 | 0.63 | 0.5 | 0.61 | 0.49 | 0.62 | 0.46 |
| | Traditional | 2.21 | 1.94 | 1.73 | 1.59 | 1.5 | 1.09 | 0.68 | 0.65 | 0.51 | 0.58 | 0.49 | 0.56 | 0.83 | 0.42 | 0.43 |
| 20 | CrossFit | 2.5 | 1.63 | 1.53 | 1.43 | 1.5 | 1.2 | 0.65 | 0.59 | 0.59 | 0.49 | 0.56 | 0.51 | 0.52 | 0.54 | 0.51 |
| | Traditional | 2.34 | 1.7 | 1.43 | 1.38 | 1.34 | 1.03 | 0.52 | 0.49 | 0.41 | 0.4 | 0.4 | 0.38 | 0.31 | 0.47 | 0.2 |
| 21 | CrossFit | 3.44 | 2.21 | 1.93 | 1.76 | 1.68 | 1.49 | 1.03 | 0.86 | 0.85 | 0.81 | 0.78 | 0.73 | 0.72 | 0.71 | 0.67 |
| | Traditional | 3.24 | 2.2 | 1.77 | 1.65 | 1.6 | 1.25 | 0.77 | 0.68 | 0.59 | 0.69 | 0.59 | 0.58 | 0.65 | 0.66 | 0.53 |
| 22 | CrossFit | 2.16 | 1.32 | 1.52 | 1.51 | 1.49 | 1.37 | 0.83 | 0.56 | 0.54 | 0.53 | 0.53 | 0.45 | 0.51 | 0.41 | 0.46 |
| | Traditional | 2.07 | 1.41 | 1.25 | 1.16 | 1.11 | 0.77 | 0.28 | 0.22 | 0.28 | 0.14 | 0.1 | 0.12 | 0.1 | 0.11 | 0.21 |
| 23 | CrossFit | 2.6 | 2.1 | 1.8 | 1.61 | 1.55 | 1.26 | 0.96 | 0.76 | 0.95 | 0.83 | 0.78 | 0.72 | 0.76 | 0.67 | 0.69 |
| | Traditional | 2.43 | 1.76 | 1.49 | 1.48 | 1.32 | 1.12 | 0.88 | 0.84 | 0.68 | 0.77 | 0.57 | 0.75 | 0.81 | 0.66 | 0.67 |
| 24 | CrossFit | 3 | 2.15 | 2.12 | 1.84 | 1.8 | 1.74 | 1.22 | 0.84 | 0.75 | 0.78 | 0.62 | 0.66 | 0.56 | 0.49 | 0.61 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Traditional | 2.92 | 1.82 | 1.48 | 1.52 | 1.44 | 1.1 | 0.53 | 0.37 | 0.4 | 0.43 | 0.4 | 0.35 | 0.44 | 0.49 | 0.43 |
| 25 | CrossFit | 3.73 | 1.84 | 1.86 | 1.66 | 1.73 | 1.58 | 1.71 | 1.08 | 0.71 | 0.57 | 0.67 | 0.48 | 0.49 | 0.58 | 0.32 |
| | Traditional | 2.85 | 1.95 | 1.65 | 1.43 | 1.46 | 1.23 | 0.66 | 0.56 | 0.51 | 0.51 | 0.57 | 0.47 | 0.46 | 0.43 | 0.45 |
| 26 | CrossFit | 1.7 | 1.23 | 1.31 | 1.35 | 1.2 | 0.92 | 0.51 | 0.43 | 0.55 | 0.3 | 0.37 | 0.3 | 0.3 | 0.34 | 0.27 |
| | Traditional | 1.66 | 1.24 | 1.23 | 1.1 | 1.03 | 1.07 | 0.73 | 0.45 | 0.37 | 0.34 | 0.42 | 0.45 | 0.42 | 0.41 | 0.35 |
| 27 | CrossFit | 2.78 | 2.36 | 2.05 | 1.71 | 1.61 | 1 | 0.84 | 0.74 | 0.78 | 0.68 | 0.6 | 0.58 | 0.53 | 0.47 | 0.47 |
| | Traditional | 2.75 | 2.02 | 1.73 | 1.75 | 1.56 | 1.29 | 0.86 | 0.76 | 0.58 | 0.56 | 0.62 | 0.48 | 0.7 | 0.66 | 0.56 |
| 28 | CrossFit | 2.81 | 1.6 | 1.47 | 1.33 | 1.3 | 0.98 | 0.6 | 0.52 | 0.6 | 0.45 | 0.57 | 0.42 | 0.49 | 0.24 | 0.41 |
| | Traditional | 2.25 | 1.34 | 1.1 | 1.03 | 1.03 | 0.84 | 0.47 | 0.35 | 0.36 | 0.3 | 0.28 | 0.3 | 0.26 | 0.31 | 0.29 |
| 29 | CrossFit | 2.85 | 1.42 | 1.73 | 1.7 | 1.62 | 1.6 | 1.04 | 0.74 | 0.64 | 0.73 | 0.65 | 0.66 | 0.66 | 0.67 | 0.65 |
| | Traditional | 2.59 | 1.85 | 1.56 | 1.49 | 1.41 | 1.13 | 0.71 | 0.49 | 0.59 | 0.54 | 0.48 | 0.42 | 0.49 | 0.46 | 0.42 |
| 30 | CrossFit | 1.82 | 1.32 | 1.39 | 1.34 | 1.32 | 1.16 | 0.56 | 0.54 | 0.57 | 0.53 | 0.38 | 0.41 | 0.34 | 0.41 | 0.35 |
| | Traditional | 1.58 | 1.34 | 1.31 | 1.22 | 1.16 | 1.06 | 0.69 | 0.37 | 0.34 | 0.38 | 0.23 | 0.25 | 0.29 | 0.27 | 0.24 |
| Average M | CrossFit | 2.65 | 1.74 | 1.68 | 1.56 | 1.52 | 1.28 | 0.89 | 0.69 | 0.7 | 0.6 | 0.58 | 0.54 | 0.53 | 0.51 | 0.5 |
| | Traditional | 2.44 | 1.73 | 1.47 | 1.39 | 1.34 | 1.06 | 0.64 | 0.51 | 0.46 | 0.47 | 0.42 | 0.43 | 0.48 | 0.44 | 0.39 |
| Std. Dev. M | CrossFit | 0.61 | 0.38 | 0.27 | 0.19 | 0.22 | 0.3 | 0.32 | 0.17 | 0.1 | 0.15 | 0.14 | 0.13 | 0.12 | 0.13 | 0.15 |
| | Traditional | 0.45 | 0.29 | 0.2 | 0.21 | 0.19 | 0.15 | 0.16 | 0.17 | 0.11 | 0.16 | 0.15 | 0.15 | 0.2 | 0.15 | 0.13 |
| Combined Mean | CrossFit | 2.22 | 1.47 | 1.42 | 1.32 | 1.29 | 1.06 | 0.75 | 0.57 | 0.5 | 0.49 | 0.48 | 0.45 | 0.43 | 0.41 | 0.41 |
| | Traditional | 2.07 | 1.48 | 1.26 | 1.2 | 1.17 | 0.9 | 0.55 | 0.44 | 0.41 | 0.4 | 0.39 | 0.36 | 0.4 | 0.36 | 0.36 |
| Combined Std. Dev. | CrossFit | 0.65 | 0.4 | 0.34 | 0.29 | 0.3 | 0.33 | 0.3 | 0.18 | 0.2 | 0.16 | 0.16 | 0.15 | 0.14 | 0.15 | 0.14 |
| | Traditional | 0.51 | 0.34 | 0.27 | 0.26 | 0.25 | 0.22 | 0.17 | 0.14 | 0.1 | 0.14 | 0.14 | 0.13 | 0.17 | 0.14 | 0.11 |

APPENDIX G

STATISTICAL TESTS

## Traditional vs. CrossFit® Energy Expenditure

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | EEcrossfit - EEacsm | 37.51902 | 33.51910 | 6.11972 | 25.00278 | 50.03526 | 6.131 | 29 | .000 |

## Traditional vs. CrossFit® Energy Expenditure per Minute

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | EEMINcrossfit - EEMINacsm | .27533 | .45007 | .08217 | .10727 | .44339 | 3.351 | 29 | .002 |

## Traditional vs. CrossFit® 15 min Recovery $VO_2$

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | avgXFIT - avgTRAD | .10467 | .11365 | .02075 | .06223 | .14710 | 5.044 | 29 | .000 |

## Traditional vs. CrossFit® Peak Heart Rate

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | HRxfit - HRtrad | 17.111 | 7.827 | 1.506 | 14.015 | 20.207 | 11.360 | 26 | .000 |

## Traditional vs. CrossFit® Peak $VO_2$

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | MaxVO2crossfit - MaxVO2acsm | .41333 | .26073 | .04760 | .31597 | .51069 | 8.683 | 29 | .000 |