UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

# DETERMINING THE ENERGY EXPENDITURE AND RELATIVE INTENSITY OF TWO CROSSFIT WORKOUTS

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science, Clinical Exercise Physiology

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May, 2013

DETERMINING THE ENERGY EXPENDITURE AND RELATIVE INTENSITY OF TWO CROSSFIT WORKOUTS

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# ABSTRACT

Babiash, P.E. Determining the energy expenditure and relative intensity of two CrossFit workouts. MS in Clinical Exercise Physiology, May 2013, 42pp. (J. Porcari)

This study was designed to determine the energy expenditure and relative intensity of two Crossfit workouts. Fifteen subjects (7 males, 8 females) performed a $VO_2$max test before participating in the CrossFit workouts. Additionally, subjects completed two different CrossFit workouts, which included a similar number of sets and repetitions. Each workout included a 5-minute warm-up, a skill phase, a workout of the day (WOD), and a 5-minute cool-down phase. During the CrossFit workouts heart rate was measured every minute using radiotelemetry. Subjects reported rating of perceived exertion (RPE) after each set of exercises and upon completion of the workout using the 6-20 Borg scale. Males had a significantly higher $VO_2$, session RPE, and energy expenditure during both workouts compared to females. Heart rates were elevated to 90% of HRmax, and $VO_2$ reached 80% $VO_2$max in both workouts. Both values fall within the training range recommended by ACSM for improving cardiorespiratory endurance.

ACKNOWLEDGEMENT

I would like to say how grateful I am for being able to be a part of one of the best programs for Clinical Exercise Physiology in the United States. This past year has helped to shape me into the person I am today, and who I will become in the future as I continue on as an Exercise Physiologist.

I would like to thank you committee chair Dr. John Porcari for guiding me through this long process. All of your assistance has been greatly appreciated. I would also like to thank Scott Doberstein and Dr. Jeff Steffen for being on my thesis committee and helping make this study possible.

To my parents for always believing in me the past few years, I do not know where I would be without your outstanding support. I would not be where I am today without everything that you have done for me.

Finally, to my classmates, whom have shared the stress of completing a Master's degree in one year, thank you for your support. I wish you all the best as we venture onto our next journey in life in the professional world. You will all do great!

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## INTRODUCTION

Every year new exercise programs are being developed in order to help promote physical fitness. CrossFit training has become a popular form of exercise in the past couple of years and has even developed into a competitive sport. CrossFit is an exercise training program that aims to improve fitness through the utilization of a constant variety of functional movements (Glassman, 2007). Two of the main methods combined to form a CrossFit workout are high-intensity interval training (HITT) and circuit weight training (CWT). HITT involves performing repeated bouts of “all-out” exercise, with short rest periods between bouts. The high-intensity segments are performed relatively close to maximal oxygen consumption ($VO_2max$) (Gibala & McGee, 2008). CWT involves performing resistance-training exercise for a given period of time (e.g., 30 seconds) and then moving on to the next exercise with minimal rest between exercise (e.g., 30 seconds) (Rixon, Rehor & Bemben, 2006). The resistance used for CWT is usually 40-70% of 1 repetition maximum (RM) and individuals perform as many repetitions as possible during the 30-second work segment.

CrossFit training includes rowing, sprinting, powerlifting, gymnastics, calisthenics, and weight lifting, but it is not limited to just these exercises. CrossFit workouts are typically centered on a “Workout of the Day” (WOD). While performing the WOD, participants are being timed while they perform the given exercises at near maximum exertion levels (Glassman, 2002). Paine et al. (2010) conducted a 6-week CrossFit training study using the Armed Forces. The CrossFit training program consisted of four, 1 hour training sessions per week. The main finding of the study was that the subjects had a 20% increase in overall work capacity.

CrossFit uses CWT as a component of their high-intensity workouts. Gettman and Pollock (1981) reviewed CWT and concluded that a CWT program would only increase $VO_2$max to a modest degree. The average increase was 4.3% for males and 8.0% for females. Within the review, they reported that CWT expended an average of 9.6-9.9 kcals per minute. In 2011, a study was conducted to determine the energy cost and exercise intensity of four diverse P90X workouts. P90X is an exercise program that combines CWT and aerobic exercise routines. Woldt et al. (2011) found that HR during the four workouts averaged 75% of heart rate maximum (HRmax) for males and 78% of HRmax for females. The average percentage of $VO_2$max was 58% for males and 64% for females, respectively. From these results Woldt et al. (2011) concluded that all four P90X workouts met American College of Sport Medicine (ACSM) recommendations for energy cost and exercise intensity (ACSM, 2010).

CrossFit founders call their overall approach “evidence-based fitness”, which is supported by measureable, observable, and repeatable facts (Glassman, 2007). However, despite these claims, it is unknown if these workouts meet ACSM (2010) guidelines for relative exercise intensity and energy expenditure. Therefore, the purpose of this study was to determine the energy expenditure and relative exercise intensity of two separate CrossFit workouts.

# METHODS

## Subjects

Subjects in this study were 15 apparently healthy adults between 20 - 47 years of age. Each subject was either familiar with HITT and CWT or had previous CrossFit experience. Each subject completed a Physical Activity Readiness-Questionnaire (PAR-Q) form prior to being admitted into the study. The PAR-Q (APPENDIX A) is designed to screen for major health problems that would exclude subjects from participation. The study was approved by the University of Wisconsin- La Crosse Institutional Review Board for the Protection of Human Subjects and the subjects provided written informed consent (APPENDIX B) prior to participation.

## Procedures

Initially, each subject performed a maximal exercise test on a motorized treadmill. The test began with the subjects walking or running at a comfortable, self-selected pace, without any incline. The speed stayed the same and grade increased 2.5% every 2 minutes until volitional exhaustion. Throughout the test, HR was measured each minute using radiotelemetry (Polar Electro Oy, Plymouth, NY) and $VO_2$ was measured using open circuit spirometry (AEI, Pittsburgh, PA). Blood lactate concentration was obtained at the beginning and upon completion of each CrossFit workout using a finger prick blood sample. Blood lactate was determined using a blood lactate analyzer (NOVA, Waltham, MA). After each 2-minute stage a rating of perceived exertion (RPE) was recorded using the 6-20 Borg scale (Borg, 1973). The purpose of this maximal exercise test was to determine each subject's HRmax and $VO_2$max. Additionally, a HR/$VO_2$ regression equation was developed for each subject using the stage-by-stage HR and $VO_2$ data. This regression equation was used to predict energy expenditure during the CrossFit workouts.

Prior to completing the CrossFit workout, each subject practiced selected exercises until the head investigator felt they were proficient. Each subject then performed two different CrossFit workouts. Each workout included a 5-minute warm-up, a skill phase, a WOD, and a 5-minute cool-down phase. The first WOD (Donkey Kong) incorporated the following exercises: burpees, kettlebell swings, and box jumps. Each exercise was performed three times, with the number of repetitions decreasing each time. During the first round each exercise was performed 21 times, the second round 15 times, and the final round 9 times. The second WOD (Fran) contained just two exercises: thrusters and assisted pull-ups. This WOD was performed in the same sequence as the first. These WODs are based on the idea of completing all of the repetitions in the shortest amount of time possible. HR was recorded every minute during the exercise sessions using radiotelemetry and a RPE was taken after each round. Additionally, an overall session RPE was taken at the end of the workout.

At the conclusion of each WOD, exercise HR's were inserted into each subject's previously developed HR/$VO_2$ regression equation. This predicted the $VO_2$ that each of the subjects exercised at during the CrossFit workout session. Energy expenditure (kcals) was calculated from the predicted $VO_2$ data assuming a constant of 5 kcal per L of $O_2$ consumed.

## STATISICAL ANALYSIS

Descriptive statistics were used to characterize the subject's population and determine average workout data. Repeated measures ANOVA were used to compare $VO_2$, HR, lactate, RPE, and kcals for both CrossFit workout sessions. Alpha was set at $p = <.05$ to achieve statistical significance. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS, Version 19; SPSS Inc., Chicago, IL.)

## RESULTS

Descriptive characteristics of the subjects are presented in Table 1. There was no significant difference in age between males and females. As expected, males were significantly heavier and taller than females. Males also had significantly higher maximal oxygen consumption ($VO_2max$).

Table 1. Descriptive characteristics of the subjects

| | Female (n=8) | Male (n=7) |
|---|---|---|
| Age (years) | 28.4± 9.27 | 34.7± 8.60 |
| Height (cm) | 170.5± 8.63 | 181.8± 6.37* |
| Weight (kgs) | 71.9± 11.97 | 92.9± 8.99* |
| HRmax (bpm) | 183± 10.9 | 178± 12.7 |
| $VO_2$max (ml/kg/min) | 42.9± 11.27 | 54.4± 9.71* |

*Significantly different ($p < .05$).
Values represent Mean ± SD.

The physiological responses to the two CrossFit workouts are summarized in Table 2. The HR, $VO_2$, and RPE responses during each round of each CrossFit workout are graphically presented in Figures 1-3, respectively. Overall, there were no significant differences in average HR, % HRmax, change in lactate, $VO_2$ or % $VO_2$max between workouts. Males were found to have significantly higher $VO_2$, session RPE, and kcals during both CrossFit workouts compared to females. For females, session RPE for CrossFit workout 1 was significantly higher than the session RPE for CrossFit workout 2.

Table 2. Average exercise responses to the two CrossFit workouts.

| | CrossFit Workout 1 | CrossFit Workout 2 |
|---|---|---|
| Heart Rate (bpm) | | |
| Females | 167 ±7.56 | 158 ±13.9 |
| Males | 162 ±12.5 | 160±7.33 |
| % HR max | | |
| Females | 91 ±5.4 | 86 ±7.4 |
| Males | 91 ±3.7 | 90 ±5.5 |
| $VO_2$ (ml/kg/min) | | |
| Females | 36.6 ±9.14 | 32.4 ±5.31 |
| Males | 44.8 ±7.75* | 44.2 ±8.85* |
| % $VO_2$ max | | |
| Females | 86 ±6.0 | 78 ±13.9 |
| Males | 83 ±4.7 | 81 ±10.2 |
| Kcals | | |
| Females | 12.9 ±2.74 | 11.6 ±2.22 |
| Males | 20.6 ±2.80* | 20.4 ±3.69* |
| Session RPE | | |
| Females | 16.9 ±0.99 | 15.3±1.17# |
| Males | 16.1 ±1.54* | 14.3±1.25#* |
| Change in Lactate | | |
| Females | 10.2 ±3.20 | 8.46 ±1.88 |
| Males | 11.6 ±2.96 | 11.0 ±4.41 |
| Time (sec) | | |
| Females | 545 ±155 | 331±82.4# |
| Males | 494 ±108 | 331±92.1# |

# Significantly different than workout 1 (p<.05).

* Significantly different than females (p<.05).

Values represent Mean ± SD.

The HR responses during the three rounds of CrossFit workout 1 and CrossFit workout 2 are presented in Figure 1. During the first round of both workouts HRs were elevated to an average of 90% of HRmax, which was maintained throughout the remainder of the workout. The dashed lines represent 64-94% HRmax, which represents the training range recommended by ACSM (2010) for improving cardiorespiratory endurance. There were no significant differences in the HR responses between workouts 1 and 2.

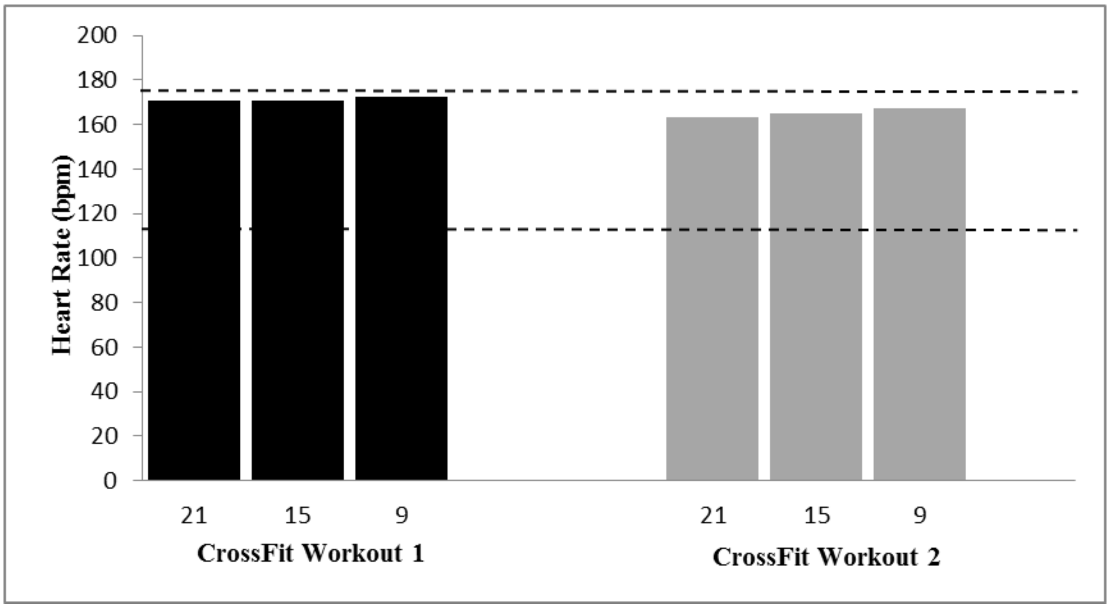


Figure 1. Heart rate responses during the three sets of CrossFit workouts 1 and 2.

Oxygen consumption during the three rounds of CrossFit workouts 1 and 2 are presented in Figure 2. Similar to the HR responses, $VO_2$ increased immediately during the first round of both workouts and increased slightly with subsequent rounds. There were no significant differences in the $VO_2$ responses during workout 1 and 2. The dashed lines represent 40-85% of % $VO_2$max, which represents the training range recommended by ACSM (2010) for improving cardiorespiratory endurance.

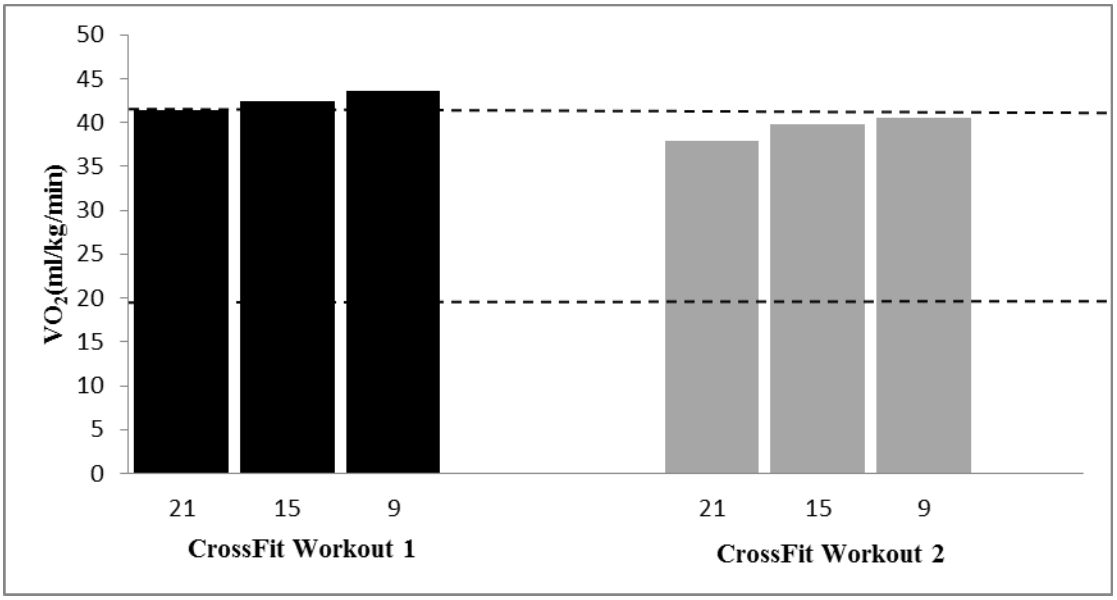


Figure 2. Oxygen consumption responses during the three sets of CrossFit workouts 1 and 2.

During both CrossFit workouts, subjects were asked to rate the level of difficulty after the rounds of 21, 15 and 9 repetitions using the 6-20 Borg Scale (Borg, 1973). RPE data during each round of the CrossFit workouts are presented in Figure 3. RPE values during workout 2 were significantly lower than workout 1.

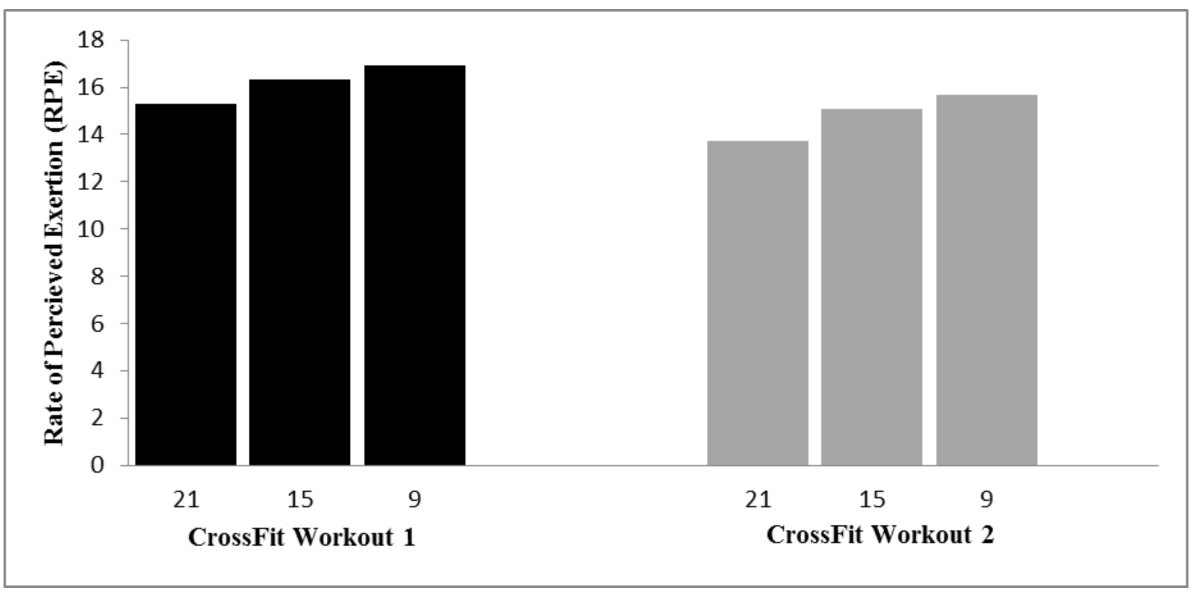


Figure 3. Rating of perceived exertion (RPE) during CrossFit workouts 1 and 2.

# DISCUSSION

The objective of this study was to determine the energy expenditure and relative intensity of two different CrossFit exercise sessions. We tested two similar, repetition-based CrossFit WOD. The workouts consisted of different exercises, but utilized the same number of repetitions and sets. It was found that HR's were elevated to an average of 90% of HRmax during the first round of both workouts and these HR's were maintained throughout. Similar to the HR responses, $VO_2$ increased immediately during the first round of both workouts and increased slightly during the latter two rounds. HR and $VO_2$ values during both CrossFit workouts fall within ACSM's (2010) recommended ranges of 64-94% of HRmax and 40-85% of $VO_2$max.

Energy expenditure was calculated from the $VO_2$ data. When this was done, caloric expenditure averaged 20.5 kcal/min in men and 12.3 kcal/min in females. The amount of time it took each participant to complete the WOD's varied greatly, which affected the total number of calories expended during each workout. Males burned an average of 169.6 calories for workouts 1 (average time of 8 minutes, 23 seconds) and 112.5 calories for workout 2 (average time of 5 minutes, 52 seconds). Females averaged 117.2 calories for workout 1 (average time of 9 minutes, 8 seconds) and 63.9 calories for workout 2 (average time of 5 minutes. 52 seconds).

Previous studies have found that interval training can offer greater increases in $VO_2$max in a shorter period of time compared to continuous, long-duration training

(Godin et al., 1994). The main factor in determining increases in $VO_2$max is exercise intensity; the greater the intensity of the exercise, the greater the increase in aerobic capacity. In the current study, HR averaged 90% HRmax and $VO_2$ averaged 80% of $VO_2$max during both CrossFit workouts. These values are at the higher end of the recommended training range recommended by ACSM (2010) for increasing cardiorespiratory endurance. This indicates that subjects were well above their anaerobic thresholds for the CrossFit workouts. This helps to explain why HITT results in greater increase in aerobic capacity compared to traditional aerobic training, which is typically performed well below an individual's anaerobic threshold.

The vigorous intensity of a CrossFit workout was further supported by the blood lactate values. Absolute values averaged 15.9 for men and 12.4 for women indicating that subjects were well above their lactate threshold, which is usually defined as 4 mmol/l (Foster & Cotter, 2005).

One of the most important factors affecting the likelihood of participating in exercise for most individuals is time. The use of HITT is a favorable option for those people with time constraints. The present study included two workouts that were completed in less than 12 minutes, not including the warm-up and cool-down portions of the workout. Despite this short duration, subjects still burned an average of 115.8 calories.

The session RPE values were markedly higher during Donkey Kong (workout 1) than Fran (workout 2). However, both workouts would be rated as "hard" exercise when looking at the verbal anchor points on the 6-20 Borg scale (Borg, 1973).

Consistent with the intensity data found in the present study, Smith et al. (2013) found that a CrossFit-based high intensity power training (HIPT) program significantly improves $VO_2$max and body composition in males and females across a wide range of fitness levels. The study involved 43 subjects (23 males, 20 females) who completed a 10-week CrossFit-based program. $VO_2$max values were measured at the start of the program and upon completion. Results showed a significant improvement in $VO_2$max in both males (43.10 to 48.96) and females (35.98 to 40.22). There was also a significant decrease in body fat in both males (22.2% to 18.0%) and females (26.6% to 23.2%). These improvements were found across all levels of fitness and in both genders.

The outcome of this study indicates that a CrossFit workout meets ACSM (2010) guidelines for energy expenditure and exercise intensity. This indicates that it is an effective and relatively quick mode of exercise for those who find it hard to find time to exercise. Further testing is needed to determine the long-term physiological effects of CrossFit workout training.

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APPENDIX A

PAR-Q

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

# PAR-Q & YOU

**(A Questionnaire for People Aged 15 to 69)**

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

| 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 (for example, back, knee or hip) 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 one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

## NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

**DELAY BECOMING MUCH MORE ACTIVE:**

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

**PLEASE NOTE:** If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

**No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.**

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ________________________________________

SIGNATURE ____________________________ DATE ____________________________

SIGNATURE OF PARENT
or GUARDIAN (for participants under the age of majority) ____________________________ WITNESS ____________________________

**Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.**

1:12

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APPENDIX B

INFORMED CONSENT

## INFORMED CONSENT

## DETERMINING THE ENERGY COST AND EXERCISE INTENSITY OF A CROSSFIT WORKOUT SESSION

I, ________________________________, volunteer to participate in a research study being conducted at the University of Wisconsin-La Crosse

### Purpose and Procedures

- The purpose of this study is to evaluate the energy expenditure and exercise intensity of a CrossFit workout session.
- My participation in this study will consist of three separate sessions.
- The first session will include a maximal exercise test on a motorized treadmill. The test will start out at a low level of speed and grade and will gradually increase until I can no longer continue. During the test I will wear a facemask to collect expired air and a chest strap to measure heart rate.
- Each of the next two sessions will include a single CrossFit workout. Each workout include a 5-minute warm-up, a short skills session, a CrossFit "Workout of the Day", and a 5-minute cool-down. During these workouts I will wear a chest strap to measure my heart rate. A sampling of my blood will also be taken using a finger prick two times to help determine my blood lactate.
- The total time requirement for this study will be between 3-4 hours.
- Testing will take place in Mitchell Hall on the University of Wisconsin-La Crosse campus.
- Research assistants will conduct research under the direction of Dr. John Porcari, a Professor in the Department of Exercise and Sport Science.

### Potential Risks

- I may experience overall muscle fatigue, muscle soreness, and shortness of breath as the result of the workouts in this study.
- There is the risk of pulled muscles and other minor injuries that may occur as with any other type of aerobic or resistance training workout.
- The risk of serious or life-threatening complications (e.g., heart attack, stroke, death) is extremely low (<1/10,000 tests) in apparently health adults.
- If complications occur the testing will be stopped immediately.
- There will be persons trained in Advanced Cardiac Life Support and CPR available during every testing session.

**Benefits of Participation**

- By volunteering in this study, I will gain a better overall understanding of my personal physical fitness level and my maximal heart rate.
- This study will be beneficial to exercise professionals, researchers, and the general public who are interested in learning the effectiveness of CrossFit workouts for controlling body weight and improving cardiorespiratory fitness.
- I will receive $10.00 if I complete all of the testing in the study.

**Rights and Confidentiality**

- My participation is voluntary and I may choose to discontinue my involvement in this study without any penalty.
- The results of this study have the potential to be published or presented at professional meetings, but only group data will be presented.

I have read the information provided in this consent document. I have been informed of the purpose of this study, the procedures, and the expectations of the investigators and myself. I have asked questions on information that concerns me and received clear answers so that I fully understand all aspects of the study.

Questions and concerns regarding this study procedure may be directed to Paige Babiash (608-792-4330), the principal investigator, or the study advisor Dr. John Porcari, Department of Exercise and Sport Science, UW-L (608-785-8684). Questions that may regard the protection of human subjects may be addressed to the University of Wisconsin- La Crosse Institutional Review Board for the Protection of Human Subjects at (608-785-8124) or (irb@uwlax.edu).

Participant's Name: ______________________________________________________

Participant's Signature: ______________________________ Date: ___________________

Researcher's Signature: ______________________________ Date: ___________________

# APPENDIX C

# REVIEW OF LITERATURE

## REVIEW OF LITERATURE

New exercise programs are constantly being introduced to attempt to keep people motivated to improve physical fitness. Many of these programs are combining aerobic exercise and resistance training in a circuit to help improve cardiorespiratory fitness, amount of calories burned, and add strength in a short amount of time. CrossFit, a training program that combines multiple methods into a single high-intensity, short-duration workout, has become increasingly popular over the last couple of years. The problem is that very little research has been performed to test the validity of a CrossFit workout for cardiorespiratory fitness or energy expenditure relating with the American College of Sports Medicine (ACSM, 2010). Therefore, the purpose of this review is to review current literature that focus on similar workouts in relation to CrossFit. The following review will focus on exercise recommendations and benefits, circuit training, high-intensity interval training, energy expenditure, and CrossFit itself.

### Exercise Recommendations and Benefits

ACSM (2010) provides guidelines for all types of exercise prescription such as benefits of resistance training, improving cardiorespiratory fitness, and appropriate energy expenditure (kcals) levels. To improve and maintain cardiovascular fitness the ACSM (2010) recommends individuals should exercise at an overall intensity of at least 64/70-94% of heart rate maximum (HRmax) or between 30/40-85% of maximal oxygen consumption ($VO_2$max). Each exercise session one should expend 150/300-400 kcals and a minimum of ~1,000 kcals per week. A weekly energy expenditure of ~2,000 kcals has been shown to be a successful way to maintain short-term and long-term weight control. If minimum total of ~1,000 kcals is expended it has been shown to decrease the risk of all-cause mortality by 20 to 30%. ACSM (2010) claims that long-term aerobic exercise programs include many health benefits as well. These include reduced risk of diabetes, reduced blood pressure and decreased risk of premature death. They also claim that resistance exercise has the ability to reduce risk of back pain, diabetes, and hypertension. This includes the claim that circuit weight training (CWT) can increase individuals $VO_2$max up to 6% (ACSM, 2010).

## High-Intensity Interval Training

**$VO_2$max and Endurance.** One of the best ways to determine an individual's overall fitness is by their $VO_2$max. This is the maximum capacity of the body to transport and utilize oxygen for energy production. $VO_2$max is the point at which the oxygen consumption plateaus, which is measured by an incremental exercise test that is done to the point of exhaustion. $VO_2$max testing may also be able to provide other useful information including an individual's HRmax, lactate threshold (LT), ventilatory threshold (VT), and maximum power output (POmax).

Helgerud et al. (2007) studied the effects of aerobic endurance training at different intensities. Forty healthy, moderately trained subjects were randomly assigned to one of four groups. These four training groups consisted of: long slow distance, lactate threshold, 15/15 interval running, and 4 x 4 minutes of interval running. Long slow distance was at 70% HRmax and lactate threshold was 85% HRmax. The 15/15 interval running group had 15 seconds of running at 90-95% HRmax immediately followed by 15 seconds of active resting at 70% HRmax. The final group of 4 x 4 minute interval running ran 4 minutes at 90-95% HRmax followed by 3 minutes of active resting at 70% HRmax. Each training group performed these protocols 3 days a week for 8 weeks.

Both of the high-intensity aerobic interval training groups had a significant increase in $VO_2$max when they were compared to the other two training groups. The 15/15 interval group increased by 5.5% and the 4 x 4 interval group by 7.2%, and there was a 10% increase in stroke volume (SV) after interval training. The relationship between the changes in $VO_2$max and SV closely relate to the systems involved in $VO_2$max. The respiratory system and the circulatory system are two major contributors to an individual's $VO_2$max. With proper exercise training, respiration becomes more efficient and SV increases, which allows for the muscles to adapt and utilize oxygen in a more resourceful manor (Sherwood, 2007).

Tabata et al. (1996) also studied the effects of training intensity on $VO_2$max. This study involved of two different training experiments that incorporated the use of a braked cycle ergometer. The first experiment was 6 weeks in length and subjects exercised 5 days a week at 70% of $VO_2$max. Each training session was 60 minutes long, and as each subjects $VO_2$max increased the exercise intensity was increased to maintain 70% of their actual $VO_2$max. Therefore, $VO_2$max was measured before training and after training, as well as every week during the 6-week training period. Maximal accumulated oxygen deficit was also measured at the beginning of the study, at 4 weeks, and after training. There was a significant increase in $VO_2$max during training.

Tabata and colleagues (Tabata et al., 1996) second experiment was designed to quantify the effect of high-intensity intermittent training (HIIT) on kcals. Seven subjects participated in exercise 5 days a week for 6 weeks. The intermittent training consisted of of seven to eight sets of 20 seconds of exercise at an intensity equal to 170% of $VO_2$max. These bouts of exercise were each followed by 10 seconds of rest. Exercise was terminated during each session when the pedaling frequency dropped below 85 rpm. Anaerobic capacity was determined before, at 2 weeks, 4 weeks and after training. $VO_2$max was also determined throughout the experiment. Anaerobic capacity increased by 23% after just 4 weeks of training. After the 6 weeks it had increased by a total of 28%. $VO_2$max increased by 7 ml/kg/min. These findings suggest that moderate-intensity training improves maximal aerobic power, but does not affect anaerobic capacity. Conversely, HIIT improves both energy systems efficiently.

Endurance, the measure of total time a particular aerobic activity can be maintained before fatigue is reached, is also considered to be an excellent measurement of fitness (Gibala & McGee, 2008). They found that performing HIIT for just 2 weeks has the ability to improve exercise performance and endurance. Over a 2-week period, subjects performed six sessions of HIIT. After 2 weeks, each of the subjects was able to double the amount of time they could maintain exercise at 80% of their $VO_2$max.

Gibala et al. (2008) also found changes in human muscle from short-term HIIT training. Two different groups participated in this study. The first 6 subjects performed short, intense, "all-out" bouts of exercise for 30-seconds, followed by 30 seconds of rest. The second group of subjects performed continuous exercise. The first group was required to perform approximately 9 minutes of exercise per week, whereas the second group completed close to 5 hours. Time trial performance on a stationary bike showed almost identical increases in endurance when comparing the two training groups. Muscle biopsies were done on each subject and improvements in the number and size of mitochondria within the muscle were almost identical. This study shows that in a much shorter amount of time, HIIT allows individuals to achieve many of the benefits of endurance training.

**Benefits of Interval Training in Cardiac Patients.** Interval training has also been incorporated into exercise programs for cardiac patients. There has been an abundant amount of studies done on patients with different heart conditions.

Wisloff et al. (2007) conducted a study comparing training programs of moderate versus high intensity exercise in patients with heart failure. Twenty-seven patients who were undergoing optimal medical treatment for heart failure were randomized into 3 groups; moderate continuous training, aerobic interval training, or a control group that only received advice on proper physical activity. Each session was performed 3 times a week for 12 weeks. Peak oxygen uptake ($VO_2$peak) increased 46% in the interval training group compared to only 14% in the moderate continuous training group. Left ventricular (LV) ejection fraction was increased by 35% with interval training, which shows that exercise intensity is an important factor for reversing LV remodeling and improving overall aerobic capacity and quality of life in patients with postinfarction heart failure.

Rognmo, Hetland, Helgerud, Hoff & Slordahl (2004) also conducted a study comparing moderate and high intensity exercise in patients with coronary artery disease (CAD). Twenty-one stable patients with CAD were randomized into two groups. One group participated in supervised treadmill walking at high intensity (80-90% of $VO_2$peak) and the other at a moderate intensity (50-60% of $VO_2$peak). The subjects performed these sessions 3 times a week for 10 weeks. $VO_2$peak increased by 17.9% in the high intensity group and only 7.9% in the moderate intensity group. The result of this study suggests that high intensity interval exercises are a better option for patients with stable CAD when compared to moderate intensity exercise.

Since many studies have provided evidence that HIIT is more effective than moderate intensity exercise for improving $VO_2$max in cardiac patients, Guiraud et al. wanted to take the research one step further by comparing acute cardiopulmonary responses during four different bouts of high-intensity interval exercises. The purpose of the study was to identify the most optimal training program for patients with coronary heart disease (CHD). Nineteen stable CHD patients performed four different bouts of high-intensity exercises at 100% of maximal aerobic power (MAP). Each phase varied in the duration of each interval. Phases A and B were 15 seconds and phases C and D were 60 seconds. Recovery time was also different in each phase. A and C were at 0% MAP and B and D were at 50% MAP. Perceived exertion, patient comfort and time spent above 80% was optimal during phase A, 15 second intervals with recovery at 0% MAP. The results of this study suggest its safe in stable, CHD patients to participate in exercise phases at 100% MAP.

**Metabolism.** A significant amount of research has been conducted on fat metabolism during interval training. Burgomaster, Hughes, Heigenhauster, Bradwell & Gibala (2005) conducted the effects of daily sprint training on muscle oxidative potential, $VO_2$max and endurance time to fatigue. This 2-week study involved 16 healthy subjects. Each subject had to have a pre-training muscle biopsy; once this was completed each subject completed 6 sessions of sprints in 2 weeks. Each session required an “all out” sprint on a cycle ergometer for 30 seconds repeatedly, which was followed by 4 minutes of recovery. When the 2 weeks were finished, each subject underwent a second muscle biopsy. One of the findings of this study was that citrate synthase activity increased in the training group by 38% from pre to post muscle biopsy. Activity of citrate synthase is one of the most common markers for determining muscle oxidative potential. There was also an increase in cycle endurance time to fatigue in those participating in the interval group.

A study was conducted to compare the impact of a low-volume high-intensity interval training to "all out" sprint interval training. Bayati, Farzad, Gharakhanlou & Agha-Alinejad (2011) divided 24 active males randomly into 3 groups. The 3 groups were 3-5 cycling bouts at 30 seconds all-out effort with 4 minutes of recovery, 6-10 cycling bouts at 125% maximum power with a 2 minute recovery, and a non-trained control group. Training was performed 3 times a week for 4 weeks. The results of this study agreed with the effectiveness of 30 seconds of all out training to improve aerobic and anaerobic adaptations, but it also provides evidence that low-volume high intensity training will provides similar metabolic results with more repetitions.

**Interval Training and the Overweight/Obese.** Whyte, Gill & Cathcart (2010) studied the effects of very high intensity sprint interval training on metabolic and vascular risk factors in overweight/obese sedentary individuals. Ten men completed a 2 week sprint interval training program that involved 6 sessions of 4 to 6 repeat of 30 second Wingate sprints on a braked cycle ergometer, with 4.5 minutes of recovery time between each repetition. Metabolic, anthropometric, and fitness measurements were completed before and after the 2-week training study. Insulin sensitivity and resting fat oxidation rate were significantly increased as a result of the 2-week sprint interval training. $VO_2$max, mean power, systolic blood pressure and resting carbohydrate oxidation were all significantly improved as well. Results from this study highlight the potential for sprint interval training to provide an alternative exercise model for improving metabolic and vascular health in the overweight/obese population.

**High-Intensity Intervals and Insulin Action.** There is little known about the effect of interval training on factors such as glucose and insulin levels, although it is known that aerobic exercise reduces the risk of metabolic disorders. Babraj et al. (2009) conducted a study that looked at the effects of HIIT on insulin action and glycemic control. The study involved 15 young men, who were either previously sedentary or recreationally active. All the subjects underwent a 6-week program of HIIT. The result of this study suggests that HIIT has the ability to substantially improve insulin action and glucose homeostasis in young males.

## Circuit Weight Training

In attempt to determine whether CWT could improve or maintain $VO_2$, or cause energy expenditures high enough for weight loss, Gettman and Pollock (1981) reviewed studies concerning CWT. After reviewing the literature, they concluded that the energy expenditure fell within the ACSM (2010) range for kcals per session at an average of 9.6-9.9 kcals/min, when a full exercise session was completed. The authors also concluded that CWT could cause a moderate increase in aerobic capacity with the averages for women at 8.0% and for men at 4.3%.

Gotshalk, Berger & Kraemer (2004) attempted to see if CWT could cause cardiovascular training responses by creating a high volume, prolonged, and continuous CWT protocol. There were 11 men who were physically fit and had previously participated in a resistance-training program that performed each of the 10 different lifts at 40% of 1 repetition maximum (1-RM). Each subject was to perform the circuit of 10 lifts 4 times in the same sequence with 2-5 seconds rest between sets. The subjects exercised at 39% and 50.1% of $VO_2$max respectively, which falls into ACSM's guidelines for improving and maintaining cardiorespiratory fitness. The results also showed that the HR's were also within ACSM's (2010) ranges at 71-87%. The overall results of this study suggest that continuous CWT has the ability to produce cardiovascular training responses.

Gettman and Pollock's reviews caused Wilmore et al. (1978) to conduct a study that determined the total energy cost of CWT. Forty subjects, 20 men and 20 women, who were previously involved in CWT completed this study. Each session included a 5-minute warm-up, a 22.5 minute CWT stimulus phase, and a 12 minute cool-down period. From this study the authors found that energy cost of CWT was 9.0 kcals/min for men and 6.1 kcals/min for women. This energy expenditure was similar to that of running at 5 MPH, playing an intense game of volleyball, or bicycling at 11.5 MPH.

Taskin (2009) conducted a study designed to determine the effect of circuit training on sprint-agility and anaerobic endurance. Thirty-two healthy male subjects were randomly placed into a circuit training group and a control group. The circuit training was conducted 3 days a week for 10 weeks and consisted of 8 stations, which were to be executed at 75% of maximal exertion. In order to measure sprint-agility and anaerobic endurance, Taskin (2009) used a FIFA Medical Assessment and Research Centre (F-MARC) test battery. Each participant was tested on agility and endurance both pre and post training. Results showed a significant change in both sprint-agility and anaerobic endurance. These results suggest that circuit training, when done 3 days a week for 10 weeks, has the ability to improve overall sprint-agility and anaerobic endurance.

## Energy Expenditure

There has been improved understanding of energy balance due to the measurements of various components of energy expenditure such as resting metabolic rate (RMR). Although, the duration of resting energy expenditure after vigorous exercise was yet to be measured, which caused Knab, Shanely, Corbin, Jin, Sha & Nieman (2011) to conduct a study. This study focused on the effects of adding 45 minutes of vigorous cycling bouts into a daily routine compared to a controlled resting day on 24 hours energy expenditure in a metabolic chamber. Ten male subjects completed two separate 24-hour chamber visits. One of the visits was a rest day and the other an exercise day. Daily activities were monitored to keep consistency. Knab and his associates (2011) found that 45-minute bouts of exercise increase energy expenditure by around 190 kcal for up to 14 hours after exercise. The magnitude and duration of energy expenditure after exercise may play a role in weight loss and management.

Weight management is an important concept for most individuals. Aerobic dance has been supported as a way to help with managing one's desired weight. Rixon, Rehor & Bemben (2006) performed a study that estimated energy expenditure in four different modes of aerobic dance. Twenty-eight women participates in four modes of dance; bodycombat, pump, step, and spinning. Step, Bodycombat, and spinning have a higher caloric expenditure than running at 8.05 km/hr, but lower than at 8.37 km/hr. Pump was found to have much lower energy expenditure than the other three modes of dance.

Spinning, Bodycombat, and Step aerobics, however, meet ACSM (2010) recommendations for weight loss and maintenance.

However, when it comes intermittent versus continuous exercise there is little information known on the differences of energy expenditure. Peterson, Palmer & Laubach (2004) conducted a study comparing the energy expenditure of 30 consecutive minutes at walking at a moderate intensity to 3 intermittent 10-minute bouts of moderate intensity. Twenty healthy men participated in 4 trials. The 30-minute walking and the 3 intermittent 10-minute bouts were both performed twice to test the test-retest reliability. There was no significant difference between the energy expenditure of the continuous walking versus the three bouts of walking throughout the study. Thus, the results of this study show that there is not difference in energy expenditure between doing a 30-minute bout of walking and doing 3 separate 10-minute bouts.

## CrossFit

CrossFit is core strength and conditioning program that was created in 1995 by Greg Glassman (2002). In the CrossFit Training Guide Greg Glassman (2007) states, "Our specialty is not specializing. Combat, survival, many sports, and life reward this kid of fitness and, on average punish the specialist." A typical CrossFit workout consists of a warm-up phase, a skill or strength development phase, then a "Workout of the Day" (WOD). Each CrossFit WOD design varies from day to day, but is a combination of exercises done at a high-intensity for a duration anywhere from 5 to 20 minutes.

There has been very little research conducted on the benefits of a CrossFit training program, until Paine, Uptgraft & Wylie (2010) conducted a study in 2010 with the Armed Forces. The program lasted 6 weeks and each subject was required to participate in four, 1-hour training sessions each week. The studies results showed an overall increase in work capacity in each subject with an average of 20.3% increase in $VO_2$max. Each subject also showed improvements in performance of each of the chosen exercises.

A recent study evaluated the effects of a CrossFit-based high intensity power training (HIPT) program on aerobic fitness and body composition. Smith, Sommer, Starkoff & Devor (2013) conducted a 10-week HIPT training program with 43 healthy subjects of both genders (23 males, 20 females). The study showed significant improvements of $VO_2$max in both males and females. It also found that there was a significant decrease in body fat percentage in both genders as well. These improvements were found across all levels of fitness and genders. This was the first study to report an improvement in relative and absolute $VO_2$max in response to a CrossFit-based training program. The aerobic fitness improvements are similar to those found with other HIIT programs.

## Conclusion

CrossFit has become increasingly popular over the last couple of years. Although, there are similar exercise programs that have been shown to aid in weight loss and maintenance and improve cardiorespiratory fitness, it is still unknown if CrossFit workouts can provide sufficient results that fall within ACSM (2010) recommendations. The truths about the benefits of CrossFit are as of now a mystery, which causes reason to put CrossFit workouts to the test. Therefore, the abundant amount of people around the world that are participating in CrossFit will be provided with results to help support the desired benefits.

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