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The Perceived Demands of CrossFit

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THE PERCEIVED DEMANDS OF CROSSFIT®

By

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ABSTRACT

THE PERCEIVED DEMANDS OF CROSSFIT®

By

Bryanne Bellovary

Rhabdomyolysis is the breakdown of muscle tissue causing myoglobin, creatine kinase, and other intracellular proteins and electrolytes to leak into circulation, disrupting cell homeostasis. Exertional rhabdomyolysis (ER) occurs after extremely rigorous physical training that could include high amounts of strenuous eccentric exercise. There has been an increase in reports for mild to severe ER as well as other musculoskeletal injuries as the popularity of extreme conditioning programs (e.g., CrossFit®) increases. Therefore, the main purposes of this investigation were to identify: primary risk factors associated with ER during CrossFit®, CrossFit® workouts that might induce a higher risk for the development of ER, and ratings of perceived exertion (RPE) for CrossFit® vs. American College of Sports Medicine (ACSM) training guidelines. A questionnaire was completed by 101 CrossFit® participants and 56 ACSM participants (n = 157). CrossFit® and ACSM groups reported significantly different RPEs of 7.29 ± 1.74 and 5.52 ± 1.35 ($p \leq 0.001$), and performed significantly different hard days per week of 3.99 ± 1.07 and 3.55 ± 1.39 ($p = 0.044$), respectively. The top five perceived hardest workouts based on frequency were Fran (47), Murph (27), Fight Gone Bad (10), Helen (9) and Filthy 50 (9). One occurrence of ER was reported out of 101 CrossFit® participants. Therefore, the overall risk of developing ER may be minimal, especially if a participant understands their body's limitations in regard to the intensity of CrossFit®.

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PREFACE

This thesis follows the format prescribed by the Journal of Strength and Conditioning Research (JSCR). Instructions for Authors for the JSCR can be found at this website: http://journals.lww.com/nsca-jscr/Pages/InstructionsforAuthors.aspx.

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INTRODUCTION

CrossFit® is considered a core strength and extreme conditioning program (ECP) designed to elicit a broad adaptation response (18). It mixes Olympic weightlifting, powerlifting, sprints, plyometrics, calisthenics, gymnastics, and a few “hard-to-categorize exercises” like rope climbing. Normally, CrossFit® workouts are short (usually 20 minutes or less), intense, and constantly changing by using functional movements (22,23,46). Functional movements are defined by Glassman (22) as motor recruitment patterning performed in waves of contraction from core to extremity over multiple joints. Performing these workouts allows the individual to complete all physical tasks [e.g., Olympic lifts, rope climbing, traditional sports, moving large loads over long distances quickly] and prepares them for unknown tasks [e.g., surviving fights and fires as described by CrossFit®] (18,22). CrossFit® athletes are able to perform multiple, diverse, and random physical challenges (18), which has greatly captured the attention of military, police, and firefighter personnel as well as athletes (22).

Bergeron et al. (11) suggested a need to determine the potential injury risks associated with ECPs, in particular the risk of exertional rhabdomyolysis (ER). Rhabdomyolysis is the result of muscular tissue damage leading to the release of myoglobin, creatine kinase (CK), and other cell contents into the blood stream and thereby disrupting cell homeostasis (8,12,13,27,35,38,45). When rhabdomyolysis occurs due to exercise, it is termed ER. The exercises associated with ER are typically excessive, strenuous and/or repetitive, usually eccentric in nature, and performed at intensities unaccustomed to the individual (38). Other factors related to rhabdomyolysis are dehydration, heat stress, sickle cell trait, the use of certain drugs, dietary supplements, and “high stakes training” typically undertaken by physical intensity driven professionals, such as firefighters, law enforcement personnel or military cadets (13,38).

The Center for Disease Control (CDC) reported 26,000 incidences of rhabdomyolysis per year in the United States; forty-seven percent were reported as ER (13,43). Diagnosed individuals tended to complain of muscular pain, swelling, weakness, and/or brown-, tea- or cola-colored urine (12,27,35,45). Clinical lab tests are often ordered to determine myoglobin and CK levels. If the urine test is positive for myoglobin but negative for red blood cell content and CK levels are at least five times the upper limit (35,38,45) [i.e., normal CK ranges for men are 55 to 170 IU/L and women are 30 to 135 IU/L (32)], then normally the individual is rapidly rehydrated via intravenous fluids to prevent further complications such as renal failure (35,38). Upon discharge from the hospital, ER patients are typically advised on appropriate exercise intensity and resting occurrence, proper hydration, and proper safety during high intensity workouts (17). CrossFit® is well aware of ER and has even reported occurrences among their participants.

There is a limited amount of information on CrossFit® in peer-reviewed literature. CrossFit® described their own five “victims” of ER; however, details were lacking (21). All individuals required hospitalization and made full recoveries. The author referencing these cases stated each person as having ER but no statement was made related to medical personnel diagnosing it. The author also reported that each victim was new to CrossFit® and developed ER in their first or second workout. Those who were able to perform a second session had performed it within three days after the first workout. Lastly, Glassman (21) declared that his program has never had an experienced “CrossFitter” develop ER. However, this statement was from an article (21) released by CrossFit® in 2005. In 2010, CrossFit® released another article (23) stating how CrossFit® was now designed to prevent against ER. This seemed to imply a change in CrossFit’s® design, which was to protect against ER, not cause it; even though, truly, ER might be a consequence of CrossFit® workouts.

Still, CrossFit® reportedly “defends” against ER occurrence by having workouts lasting 20 minutes or less (23). Moreover, each workout reportedly switches metabolic pathways during the session and individuals are told to control their own intensity level. They alone remain responsible for setting their own level of exertion and recognizing their body’s limitations (23). Ultimately, the discrepancy between whether CrossFit® or the individual influences the workout leads to the question, “What is the occurrence and risk associated with developing ER while performing CrossFit®?”

Therefore, the main purposes of this study were to identify: primary risk factors associated with ER during CrossFit®, CrossFit® workouts that might induce a higher risk for the development of ER, and ratings of perceived exertion (RPE) for CrossFit® vs. American College of Sports Medicine (ACSM) training guidelines. A secondary objective was to determine self-reported occurrences of diagnosed ER in exercisers. A questionnaire was developed to address these specific objectives and distributed to CrossFit® affiliates and ACSM professionals across the United States. Proposed hypotheses were: primary risk factors associated with ER during CrossFit® will be evident, certain CrossFit® workouts with an RPE of five or greater will be reported more frequently than others, the overall RPE of CrossFit® workouts will be at least rated a five or strong intensity, and CrossFit® sessions will produce a higher occurrence of ER, as compared to exercisers following ACSM guidelines.

METHODS

EXPERIMENTAL APPROACH TO PROBLEM

The methodology of the current research project utilized a questionnaire completed by exercisers to determine the most common risk factors associated with ER and self-reported RPE values reflective of workouts of the day (WODs) and various CrossFit® programs. A secondary objective of the questionnaire was to determine the possible occurrence of ER in exercisers, from beginners to advanced participants. CrossFit® members who completed a workout at a CrossFit® affiliate were included in the study. Beginners of CrossFit® workouts were surveyed because past researchers found ER development within a first or second workout (21). Other survey questions covered topics related to risks associated with ER after CrossFit® workouts, including if the person had ever developed a diagnosis of ER. Finally, in general, the questionnaire covered how participants perceived the intensity of completed workouts.

SUBJECTS

A total of 322 people responded to the request to complete the study questionnaire after IRB approval at Northern Michigan University and having all risks explained to them and giving informed consent (Appendix F). Of the total returned surveys, 203 participants completely finished it, and 157 respondents were categorized into either CrossFit® (mean ± SD; age: 34.50 ± 8.74 years; n = 101), or ACSM (mean ± SD; age: 35.41 ± 10.15 years; n = 56) exercise groups. Forty-six participants listed themselves as using some other exercise program and therefore were excluded from analysis. See Table 1 for subject characteristics.

PROCEDURES

Twenty-five out of the 50 United States were randomly selected as the questionnaire pool. As it turned out, responses were received from 35 states and Canada because participants were encouraged to spread the questionnaire to clients and fellow exercisers. To clarify, random emails were sent to 905 CrossFit® affiliates, 930 ACSM certified personal trainers, and 265 ACSM certified clinical exercise specialists after IRB approval was received. CrossFit® affiliates were gathered from the official CrossFit® website's affiliate finder. ACSM certified personal trainers were gathered via the ACSM ProFinder™. Subjects were able to answer the inquiry form at their own convenience via a website (Qualtrics) containing the questionnaire, which consisted of 19 questions completed in approximately ten minutes. The questionnaire was made available for five weeks. There was no direct contact with the participants. Because surveys were completed anonymously, no follow-up occurred and therefore the response rate was not tracked.

Notably, a pilot test performed using the current study's questionnaire determined that the questionnaire was reliable (Appendix C). Intraclass correlation values were 0.902, 0.971 and 0.801 for the questions yielding parametric results. Cohen's kappa yielded zero agreements of poor, seven agreements of slight, zero agreements of fair, three agreements of moderate, two agreements of substantial, and 25 agreements of almost perfect for the yes/no questions.

STATISTICAL ANALYSIS

Statistical analysis of the experimental data utilized an independent t-test analysis via SPSS (IBM® SPSS® Statistics Version 21). This was used to compare the statistical significance of the means for the CrossFit® group and the ACSM guided group for questions related to the average RPE for workouts, the number of weeks the individual participated in the program, and the perceived average number of hard days completed during a week. When the assumption for equality of variance was violated, as assessed by Levene's test, appropriate adjustment of the degrees of freedom was made. Chi-square analysis via crosstabulation was used to determine if a significant difference existed for the yes/no questions. Significance in this study was set to an alpha level of $p \leq 0.05$. Lastly, the frequency of the perceived hardest CrossFit® WODs was determined.

RESULTS

Using an independent t-test (with significance set at $p \leq 0.05$), the number of weeks participated in the exercise program, the average RPE reported for the programs, and the perceived number of hard days performed in a week, were all found to have significant differences between the CrossFit® and ACSM groups (Table 2). The mean number of weeks completed in the CrossFit® and ACSM groups, respectively, were 7.81 ± 0.85 and 6.38 ± 2.50. The mean RPE's reported for CrossFit® and ACSM supervised programs, respectively, were 7.29 ± 1.74 and 5.52 ± 1.35. The mean number of hard days performed or reported in a week for CrossFit® and ACSM groups, respectively, were 3.99 ± 1.07and 3.55 ± 1.39.

The remainder of the questionnaire involved yes/no questions. Statistical analysis was completed using Chi-square ($p \leq 0.05$) via crosstabulation (Tables 3 - 33). Some of the analyses had an expected count less than five. For a full list of observed counts and expected counts, see Appendix D. For the question concerning whether or not the subjects had prior exercise experience, the Pearson Chi-square was statistically significant and therefore a majority of both groups answered that they had prior exercise experience before starting either their CrossFit® or ACSM guided program. On the other hand, the Pearson Chi-square was not statistically significant whether a warm-up was completed prior to exercising. In fact, a majority of both groups answered that they completed a warm-up prior to exercise.

Another primary question was if subjects regularly took any form of medication during their respective training program. No significance was found between groups, and thus for aspirin, anti-cholinergic agents, statins, and any other medications taken, the Pearson Chi-square was not statistically significant. Notably, a majority of both groups answered that they did not take any of the previous listed medications while in CrossFit® or ACSM guided programs. The Pearson Chi-square was not computed for phenothiazines as all subjects answered “no” to taking this kind of medication. Other medications listed by the participants consisted of Adderall, allergy medications, anabolic steroids, testosterone, and diabetic insulin.

Another question with multiple parts asked if the participants had been diagnosed with a given list of conditions while attending their respective exercise program. For sickle cell trait, renal insufficiency, and heat exhaustion, the Pearson Chi-square was not completed as every subject answered no. For dehydration, fatigue, delayed onset muscle soreness (DOMS), overexertion injury, and any other medical conditions diagnosed, the Pearson Chi-square was not statistically significant. To be clear, a majority of both groups had not been diagnosed with any of the previous medical conditions while participating in either CrossFit® or an ACSM training program. Exercisers who listed other conditions were those who experienced muscle and ligament tears, tendonitis, stress fractures, and ER – which will be discussed later.

The question concerning symptoms occurring within 48-hours post exercise also had multiple parts. For excessive fatigue, muscle soreness, muscle swelling, shortness of breath, muscle weakness, muscle pain to light touch, and limited movement in the muscles used during the workout, the Pearson Chi-square was statistically significant. The percentage of the CrossFit® group who said “yes” for experiencing the previously mentioned symptoms was higher than those who said “yes” in the ACSM group. The Pearson Chi-square was not significant for experiencing sleep disturbances, chest pains, cola-/tea-/brown-colored urine, and/or any other symptom occurring within 48-hours post-exercise. Another symptom reported, but not found to be significant, by subjects in both groups; was heart palpitations.

Another primary question queried whether participants had sought medical attention due to the symptoms from the previous question (i.e., possible medical complications reported post-exercise). The Pearson Chi-square was not statistically significant because a majority of both groups answered that they had not visited a physician due to the previous symptoms in either CrossFit® or an ACSM guided group. Most participants indicated that they felt no reason to seek medical attention from the symptoms they experienced.

Another question we asked was related to ER symptoms and medical conditions diagnosed by a physician. For a positive myoglobinuria test, high serum CK levels, heart arrhythmia development, hyperkalemia development, muscle compartment syndrome, and other medical conditions diagnosed, the Pearson Chi-square was not statistically significant. A majority of both groups had not been diagnosed by a medical professional with any of the previously mentioned conditions possibly related to ER. The Pearson Chi-square was not calculated for renal insufficiency or failure and hypocalcaemia due to a “no” answer from all participants. The other listed condition diagnosed was anemia, which was reported by both participating groups but with no significant difference between them.

Next, participants were asked if they had to stay overnight at a hospital for any of the previously diagnosed conditions. The Pearson Chi-square was not statistically significant because a majority of both groups answered “no” to this question. Interestingly, a few participants also reported staying a night or longer at a hospital, which included answers of one, four, and eight nights.

In order to gain insight into the incidence of ER, the participants were asked if they had been diagnosed with ER by a physician. As a majority of both groups had not developed ER from their respective program, the Pearson Chi-square was not statistically significant. Per this sample, ER was developed by one person who was from the CrossFit® group.

Finally, only CrossFit® participants were asked to identify their perceived five hardest CrossFit® WODs (Table 34). Forty-five different workouts were mentioned with a total of 211 responses recorded. The top five most mentioned workouts were Fran (47), Murph (27), Fight Gone Bad (10), Filthy 50 (nine) and Helen (nine).

DISCUSSION

Main findings consisted of significant differences found between groups for average RPE and perceived number of hard days per week. Furthermore, non-parametric tests revealed that prior experience before starting the chosen program varied as a function of the chosen exercise program. Feelings of excessive fatigue, muscle soreness, muscle swelling, shortness of breath, muscle pain to light touch, and limited movement in muscles used during exercise within 48-hours post-exercise also varied as a function of the chosen exercise program. Therefore, the hypotheses were adequately assessed and consistent with the results. However, the possible existence of Type II error shall be discussed first.

As some of the yes/no questions yielded expected counts with less than five in the Chi-squared analysis via crosstabulation, this would increase Type II error. Therefore, those yes/no questions where p was close to 0.05 could be seen as a failure to reject the null hypothesis when the null hypothesis was actually false (28). For instance, this could be seen in the diagnosis of fatigue during the participants' respective program, where $p = 0.056$. Another example could include the question referring to the use of statins during the program, where $p = 0.056$. Other instances involved questions where significance was found. For these questions, the expected count was very close to five and they included those referring to feelings of muscle soreness (expected count for one cell was 4.64) and shortness of breath (expected count for one cell was 4.99). However, because significance was found and the null hypothesis was rejected, Type I error occurred. Another case of Type I error may be when significance was found between the number of hard days per week reported ($p = 0.044$).

Per this sample, prior exercise experience varied as a function of the exercise program the participants attended. Exercise experience consisted of at least three days per week for at least 30 minutes per day consistent with ACSM guidelines. While a majority of participants answered "yes," to having prior exercise experience, 21 (20.8%) CrossFit® participants answered "no" compared to the four or 7.1% who answered "no" from the ACSM group. The significant difference found ($p = 0.025$) is important and relates to literature describing ER to primarily affect the physically untrained (35,38,45). Because the majority of those who answered "no" were CrossFit® participants, then it is possible that CrossFit® programs could be considered excessive and repetitive with frequent use of eccentric exercise, especially with a mix of untrained individuals. Ultimately, if it is hypothesized that more beginner exercises tend to choose CrossFit®, this has the potential to be a risk factor for ER (34,38,45).

Therefore, untrained individuals new to CrossFit® should be required to perform a beginner program to minimize this risk. Despite this statement, the current sample did not contain a majority of beginners. The mean for the number of weeks completed in their respective programs was 7.81 ± 0.85 and 6.38 ± 2.50 weeks for the CrossFit® and ACSM trained groups, respectively. This reflects a possible limitation whereby novices who dropped out of their respective program were not surveyed and therefore not part of the analysis.

Researchers have found that certain medications such as aspirin, phenothiazines, anti-cholinergic agents, and statins may predispose an individual to ER (17,35,38,45). However, for the current sample, no significant differences were found between groups related to the use of certain medications. The majority of participants answered “no” to having taken a medication. However, the most commonly used medication was aspirin with 16 total participants (CrossFit® = 12 and ACSM = 4) reporting its use. The reported use of aspirin was frequently due to muscle soreness and DOMS.

Regarding the diagnosis of previous health conditions from a physical, no significant differences were found between groups. Per this sample, the participants seemed to be in good health. The most often reported health conditions were overexertion injury with seven total participants (CrossFit® = 4 and ACSM = 3) and DOMS with four total participants (CrossFit® = 3 and ACSM = 1). A few participants seemed shocked that a physician would be sought over DOMS. Though DOMS may be treated without medical attention, it should not be dismissed quickly. Notably, the signs and symptoms of acute ER can be misinterpreted as DOMS since both ER and DOMS involve damage to muscle tissue (13). It is also thought that ER exacerbates and complicates DOMS with other factors, such as the use of certain medications and prior medical history (13).

In addition to the prior mentioned risk factors, average RPE was quantitatively collected. A significant difference ($p < 0.001$) was found for the RPEs given between participants. The CrossFit® and ACSM groups reported RPEs of 7.28 ± 1.74 and 5.52 ± 1.35, respectively. Based on Borg Categorical Ratio Scale (Table 35), per this sample, the RPE of CrossFit® was considered to be *very strong* intensity as compared to a rating of *strong* intensity for an ACSM guided program (7). The hypothesis that CrossFit® exercisers would rate the program as at least a five or strong intensity was supported. In addition, ACSM exercisers also rated their program as at least a five or strong intensity. Participants also reported the number of hard days experienced in a week, where hard days had to rate as a five or above, per another part of our hypothesis. CrossFit® was reported to have an average of 3.99 ± 1.07 hard days per week per this sample. The ACSM group reported an average of 3.55 ± 1.39 hard days per week. The difference between exercise groups was found to be significantly different ($p = 0.044$). Though RPE can be affected by outside factors such as environmental temperature (7), CrossFit® was already considered to be a highly intense workout where participants were expected to perform at their personal best each session (19,23,39). Therefore, the RPEs reported based on this sample may be an accurate assessment of the average intensity levels experienced during a CrossFit® session.

Further assessment of CrossFit® workouts involved individuals listing their top five hardest WODs. These CrossFit® WODs had to have an RPE of at least five. Based on the frequency of the listed WODs, the top five most reported WODs were Fran (47), Murph (27), Fight Gone Bad (10), Helen (9), and Filthy 50 (9). The use of this frequency list may provide additional research opportunities. Whilst CK levels are the most reliable indicator of ER (32,35), the monitoring of CK levels during the top five given WODs in this paper may help determine the most taxing workouts on various skeletal muscle groups. Future comparisons could also be made to more traditional sports (e.g., weightlifting, football, and triathlon).

In addition to creating a list of the hardest CrossFit® WODs, the signs and symptoms related to ER were examined 48-hours post-exercise. All signs and symptoms of ER were experienced to some degree by both groups. However ACSM exercisers had zero participants experience cola-/tea/brown-colored urine. The CrossFit® group reported two participants. CrossFit® participants also answered “yes” to a greater extent for every sign and symptom listed (i.e., excessive fatigue, muscle soreness, muscle swelling, shortness of breath, muscle weakness, sleep disturbance, muscle pain to light touch, limited movement in muscles used during the workout, chest pain, and cola-/tea-/brown-colored urine) versus the percentage of those who answered “yes” in the ACSM group. The signs and symptoms related to ER that significantly ($p < 0.05$) varied as a function of the exercise program, whereby CrossFit® exercisers answered “yes” more often, were excessive fatigue, muscle soreness, muscle swelling, shortness of breath, muscle pain to light touch, and limited movement in the muscles used during exercise. Often muscle soreness, swelling, and pain to light touch have been reported in literature as common signs of ER in addition to brown-/tea-/cola-colored urine (13,17,32,35,38).

Of note, the one reported case of ER from a CrossFit® participant might imply an occurrence rate of 9.9 per 1000 (i.e., 1/101=0.0099). Said another way, occurrence of ER in the entire active population surveyed was 1 in 156 or approximately 6 in 1000. The individual experienced every sign and symptom listed in this paper except chest pain, and stayed at a hospital for eight nights. After analyzing individual answers, only one other CrossFit® participant reported experiencing all of these signs and symptoms except brown-/tea-/cola-colored urine. However, no ER was reported and this individual did not have any previous medical history compared to the other person's reported case in which previous instances of dehydration and overexertion injury were reported. Insofar as vigorous hydration was required for treatment, and individuals who develop ER were often advised on adequate hydration rates (13,17,27,35), low hydration levels seem to play a role in ER development. Knowingly, CrossFit® recommends individuals be properly hydrated (23).

The reports of the individuals in this paper do not represent an immediate causal relationship between their signs and symptoms observed and the development of ER. Therefore, individual exercisers should make efforts to understand their individualized response to exercise. Additionally, individual exercisers should strive to be discerning fitness industry consumers and seek out qualified health and exercise professionals. This may lead to advances in preventative consumer behavior aimed at attenuating the deleterious effects of DOMS. In the end, a fine line exists between DOMS, acute ER, and the choice of a high intensity workout (13), especially amongst motivated beginners.

PRACTICAL APPLICATIONS

Exertional rhabdomyolysis is a rare condition (13,27). While the occurrence of ER in CrossFit® is rare, per the result of this paper, it seems more exercisers undergoing CrossFit's® intense bouts report greater RPEs and hard days per week vs. ACSM driven routines. Therefore, participants of CrossFit® should strive to maintain a good understanding of their limitations during exercise in order to cope with high intensity and repetitive exercise bouts. Furthermore, all exercisers engaged in high intensity exercise should hydrate appropriately prior to exertion, and seek out a highly qualified and experienced CrossFit® or strength and conditioning professional. Ultimately, the various ways people exercise or train is ever changing, thus emphasizing the importance of up-to-date research in order to ensure the most effective, productive, and safe exercise routines are put into practice.

CHAPTER 2 LITERATURE REVIEW

INTRODUCTION

The body weight of individuals residing in the United States has progressively increased over the last few decades. At least 35.5% of men and 35.8% of women in the United States were considered obese from 2009 – 2010 (4). In an effort to get healthier, resolutions are made to lose weight and exercise (3). However, many of these resolutions go unmet due to a perceived lack of time during the individual's day to complete a well-rounded exercise program following guidelines set by the American College of Sports Medicine (ACSM) (3).

Many physicians and fitness experts accept the exercise guidelines set by the ACSM for the general population. According to ACSM (16), most adults should engage in strength exercises for two to three days per week that utilize each major muscle group, and includes the incorporation of balance, agility, and coordination. Cardiorespiratory exercises of moderate intensity should be performed five days per week for at least 30 minutes a day. However, if an individual wishes to perform these exercises at a vigorous intensity only three days per week are needed for 20 minutes a day (16). Lastly, flexibility should be incorporated into the exercise program on a minimum of two days per week and 60 seconds should be spent on each exercise (16). When examining these guidelines, overlap between exercise days is necessary to meet all ACSM criteria; such that strength, cardio-respiratory, and flexibility exercises might be performed on the same days. This could potentially make for a long workout. Thus, circuit training has evolved to shorten workouts, in some cases, while utilizing multiple aspects of training (47).

Anaerobic exercises can be combined to create a circuit training program incorporating lighter resistance (40 – 60% of a one repetition maximum) and shorter rest periods between sets (24,47). The intention is to move quickly through the exercises in a circuit while following ACSM guidelines for vigorous training, allowing for a safe and effective training program. Circuit training has evolved into extreme conditioning programs (ECP) made popular by Insanity®, P90X® and CrossFit®. These programs tend to use a variety of high intensity exercises at high volumes and timed maximal number of repetitions with short rest periods between sets (11,33). Due to the lack of research, the safety has not been defined for such programs.

The number of reported cases of muscle strains, torn ligaments, stress fractures and mild to severe cases of potentially life-threatening exertional rhabdomyolysis (ER) have increased as the popularity of ECPs grows (11,37). This is not claimed to be causal but, ECPs seem to disregard appropriate and safe training guidelines set by the ACSM for developing muscular fitness (33). For example, repetitions are performed maximally and timed with inadequate rest intervals. Experienced participants could be performing advanced exercises with excessive neuromuscular fatigue and novices could be doing too much too soon (11,34), making them potentially at risk for overuse injuries and the more serious condition, ER (33,34). Therefore, the purpose of this article is to review the literature pertaining to extreme conditioning programs, specifically CrossFit® training, ER and increasing the awareness for the possible risk of developing ER from CrossFit®. Please see Appendix A for a research-based description of CrossFit® athletes.

EXTREME CONDITONING PROGRAM

Gaining in popularity in the last 5 – 10 years, extreme conditioning programs (ECPs), such as Gym Jones®, Insanity®, P90X® and CrossFit® are characterized by the use of high intensity, aggressive training at high volume and timed, maximal number of repetitions with short rest periods between sets (11,33,37). Helping to increase the popularity of ECPs is the large number of anecdotal success stories. There are also benefits to ECPs that appeal to the general population. Specifically, time efficiency and camaraderie along with the functionality of blending strength and endurance though the variety of the workouts to minimize overuse injury and in preparations for broadening the range of physical adaptations (15). ECPs tend to contain a variety of resistance exercises coupled with body weight exercises and challenging running intervals. The high intensity state of the exercises puts moderate to high demand on the energy metabolism of active muscle fibers and the cardiovascular system. These aspects could possibly provide a reduction in body fat along with increases in muscular endurance and cardiovascular capacity (11). However, there are some perceived negative characteristics of ECPs. The high-volume nature of these training sessions can result in greater perceived effort, degradation of movement technique, decreased resistance to subsequent exercise strain, increased oxidative stress and premature feelings of fatigue (11,34). In addition, there are very few research papers on ECPs (37). This results in the concern of measureable effectiveness and safety with such programs.

One non-peer-reviewed study (40) involved using 14 subjects from the U.S. Army Command and General Staff College to determine the efficacy of CrossFit® in U.S. Army Soldiers. A six week exercise program (consisting of a minimum of four one-hour training sessions per week) was utilized with pre- and post-test assessments for each subject. The Army Physical Fitness Test (APFT) including push-ups, sit-ups and a two mile run (the two mile run was not completed post-test due to inclement weather) and three CrossFit® benchmark workouts (Fran, Fight Gone Bad and CrossFit® Total) were the focus of the testing. Unfortunately, no statistical analysis was performed and measures of aerobic fitness, strength or power were not taken. An average overall increase in work capacity of 20.33% was reported. Work capacity for Fran, Fight Gone Bad and CrossFit Total increased by 24.2%, 20.9% and 16.0% respectively. Results of the APFT for push-ups and sit-ups reported a 7.7% and 4.7% improvement respectively; however, declines in performance also occurred for some subjects. This decline was speculated to have occurred due to either an overzealous increase in load or reduction in scaling. Overall, it would seem a CrossFit program could help improve performance in some soldiers (40).

Alcaraz et al. (1) performed a study using a circuit resistance training (CRT) protocol. Though not an exact ECP routine, Alcaraz et al. (1) modified the CRT by using high-resistance instead of using typical low-resistance making it similar to ECPs. This study involved 33 subjects, divided into three groups: high-resistance circuit training (HRC), traditional high load strength training (TS) and a control group (C). The training groups utilized an eight week training period. A major finding was that the HRC resulted in improvements in strength and muscle mass similar to the TS group. This is important because previous circuit training programs using lighter loads had been unable to produce the same adaptations as TS training. Also, this study (1) was performed using healthy men with a consistent history of strength training. Previously, increases in strength results were difficult to produce in this population, suggesting that HRC could be used to increase strength and muscle mass gains in athletic populations (1). A second major finding was that HRC produces similar increases in muscular power as TS as measured using various percentages of 1RM bench press tests. This could be due to two main factors: low-repetition, high-load training demonstrates similar strength improvements to TS and that the loads lifted were lifted quickly (1). Therefore, it could be inferred that force-generating capacity and muscle shortening speed, which are two components of power, were increased, (1). With HRC being similar to ECPs (high volume, high intensity, maximal repetitions, short rest), these results could possibly be seen using an ECP; though from the literature, there does not seem to be a clear approach for initiating these types of programs and for safely progressing to harder exercises specifically for novices. Research on ECPs, more specifically CrossFit® as a mode of exercise, has only just begun.

CROSSFIT®

CrossFit® is a vastly popular fitness program. As reported by CrossFit® in an article from 2012, (23) it has grown about 50% per year based on the number of affiliates [approval and payment made to CrossFit® headquarters by the affiliate owner to use the CrossFit® name when marketing training and classes (6)] and about 90% per year based on internet activity (based on Google® Trends search interest data). This seems to be done by CrossFit® embracing a “fitness as sport” idea thru utilization of core strength and conditioning workouts designed to elicit a broad adaptation response (18,37,42).

Olympic weightlifting, powerlifting, sprints, plyometrics, calisthenics, gymnastics and a few hard-to-categorize exercises, like rope climbing, are mixed into a workout to create the workout of the day (WOD). These workouts tend to be short, intense and constantly changing by using functional movement (22,42,46) in a circuit-like training mode. The owner of CrossFit®, Glassman (22), defines functional movement as motor recruitment patterning performed in waves of contraction from core to extremity over multiple joints. CrossFit® defines fitness as the ability to do any type of real work movements (cardiorespiratory, strength, power, etc.) for any amount of time (42). In following these definitions, CrossFit® workouts prepare individuals to complete all physical and unknown tasks by keeping the training stimulus broad and constantly varied (22,37). CrossFit® athletes are able to perform multiple, diverse and randomized physical challenges (18), which has now started to draw in the general public as well as athletic, military, police and firefighter personal (22).

CrossFit® was developed to be performed in any environment: the outdoors, in an affiliated gym or in the trainees own home gym (39). CrossFit® promotes and sets out to develop total fitness which rests on a foundation set by three standards (22,42). The first encompasses improving the ten fitness domains: cardiovascular and respiratory endurance, stamina, strength, flexibility, power, speed, coordination, agility, balance and accuracy (19). The second standard is based on the performance in athletic tasks in relation to others (19). Lastly, the third involves training in all three energy systems that drive human action (19). So far there have been only a few peer-reviewed studies investigating CrossFit®.

Investigating CrossFit®

Jeffery (30) investigated whether CrossFit® effectively trains all three metabolic systems as their third standard states they do. Thirty-seven males and females were studied, divided into two groups: a CrossFit® group and a control group who trained using ACSM recommended guidelines for exercise. In order to participate in this study, participants had to have been previously training either with CrossFit® or completely following ACSM guidelines for four months (30). It would seem that subjects had self-selected their group as compared to being randomly assigned to a group. Subjects performed tests involving the Margaria Kalamen Power test, the Anaerobic Step test, the Cooper 1.5 mile run and three CrossFit® style tests: 1RM effort on a deadlift, a maximum row for meters in one minute, and a hero workout entitled "Murph" (30) which consisted of running one mile, then performing 100 pull-ups, followed by 200 push-ups, next perform 300 squats, and finish with running a mile in the shortest amount of time possible (2). Results indicated that individuals who have the highest anaerobic capacity through the ATP-PCr energy system, also have the highest aerobic capacity through the aerobic energy system (30). The CrossFit® group tended to score higher on all tests as compared to the ACSM control group (30). Therefore, Jeffery (30) concluded that CrossFit® does train all three energy systems; however the two groups seem to not be equally matched as noted by the self-selection of groups. Further research is needed to verify the other two standards of CrossFit®. Other research consists of examining whether CrossFit® improves aerobic fitness and body composition.

Smith et al. (44) looked to determine if CrossFit® improved aerobic fitness and body composition by measuring maximal oxygen consumption (VO_2 max) and present body fat, respectively. They utilized a high intensity power training (HIPT) program that involved CrossFit®-based exercises. HIPT involves a lack of prescribed rest periods, focusing on sustained high power outputs and using multi-joint movements; similar to CrossFit® (44). This study's (44) program chose to incorporate CrossFit® WODs. An example of a CrossFit® workout set up is three sets of 21, 15 and 9 repetitions of barbell front squats with overhead presses, followed by body weight pull-ups. This WOD is to be performed as quickly as possible. Other workouts may require the athlete to perform as many rounds as possible in a set amount of time. This CrossFit®-based HIPT program was carried out for 10 weeks and had 54 participants.

After the 10 week program was completed, VO_2 max improved 13.6% and 11.8% for men and women respectively. In absolute terms, body fat percentage dropped 3.7% across all subjects. However, the authors pointed out that part of the body composition changes experienced during CrossFit® training could be attributed to the Paleolithic diet that CrossFit® advises participants to follow as this diet has been shown to improve body composition on its own (44). This means that changes in body composition cannot be fully attributed to the program. Another interesting note the authors (44) made was about the number of subjects who actually completed the program.

Of the original 54 subjects who volunteered, 43 (23 males and 20 females) were able to finish the program or return for follow up testing (44). Two of the 11 who dropped out reported time concerns as their reason for discontinuing participation. The other nine participants (16% of the total recruited subject) noted overuse or injury as their reason for dropping out (44). This type of drop out occurred in spite of the author's (44) deliberate periodization of the program and required supervision by certified fitness professionals of the participants. While CrossFit®

does improve aerobic fitness and body composition, this study calls into question whether the benefits outweigh the risks of the CrossFit® program (44). This article demonstrates a need for additional research on the injury risks involved with CrossFit® and ECPs, especially as CrossFit® starts to move into university classroom settings.

Barfield et al. (10) reported that the majority of colleges and universities (about 63% as of 1998) require fitness classes for credit toward graduation. Colleges offer three different types of fitness class formats: the traditional class, the independent class and the class that is contracted out to a local exercise or sport organization (10). The traditional class is typically a basic weight training and conditioning class instructed by one of the university's faculty members or athletic coaches. This can result in proper instruction, supervision and mentoring (10). The independent class format allows the student to follow a university faculty member or athletic coach's weight training and conditioning plan without supervision (10). The contracted-out class is usually used when the university does not have the facilities for a specific activity such as golf or bowling (10). Universities will also use this format to provide their students with the opportunity to participate in the latest popular fitness program. The purpose of the Barfield et al. (10) study was to determine the students' fitness changes between fitness class formats over the course of a semester. In this study's case, the contracted-out class used here was CrossFit® (10).

Barfield et al. (10) measured the subjects' body composition using his or her body mass index (BMI), their muscular strength via hand grip dynamometer scores, muscular power via the standing long jump and muscular endurance via the number of standard pull-ups completed, the number of squat repetitions completed in one minute and the YMCA bench press test for upper body endurance. Subjects in the traditional class format had greater gains in muscular power and upper body muscular endurance. The students improved their scores by 60% for the pull-up test and improved by 90% in the standing long jump. Overall, the average improvement for students in the traditional resistance program was 20% (10).

In the independent class format the students improved their fitness the least. Hand grip strength did increase by about 11%, YMCA bench press performance increased by 30% and standing long jump performance increased by 35% (10). However, BMI increased and muscular power and upper body muscular endurance decreased in these subjects. The authors (10) deemed that the lack of results in the independent class format indicated that this format is not effective for fitness gains in a college setting.

Finally, the CrossFit® group increased their overall fitness by 17% on average (10). This group had great gains in lower body endurance. Their squat test scores improved by 70% and 60% improved their standing long jump performance. Yet when it came to upper body muscular fitness, only 50% and 40% improved in the YMCA bench press and pull-up test, respectively. The authors (10) determined that both the traditional resistance training format and the CrossFit® format would be acceptable for college credit fitness class but not the independent class format. From this, it is suggested that a CrossFit® based program could be a good addition to the credit-worthy fitness classes for college students (10). In addition to college students, CrossFit® has also extended their program to youths.

CrossFit® has developed a youth friendly program called CrossFit® Kids. The program is still considered highly intense and challenging while utilizing functional fitness (42). The difference is that the workouts are even shorter, typically 5 – 20 minutes long. The workouts are also scaled down from the adult versions to accommodate safety of the youth (42). These workouts are a part of CrossFit's® open-source internet program as well as a part of affiliate gym programs (42). Strength training youths requires that they first know proper techniques using low-resistance exercises (14), this would seem the opposite of CrossFit® Kids if it is indeed a version of the adult workouts. The American Academy of Pediatrics (14) also states that preadolescents and adolescents should avoid body building, power lifting, competitive weight lifting and maximal lifts until physical and skeletal maturity is reached. There is a lack literature on CrossFit® Kids compared to the original version. This brings up a need to analyze CrossFit® Kids to determine the efficacy and safety for youth participation as it does not seem to follow guidelines already set in place by the American Academy of Pediatrics (14). As shown in the previous literature, CrossFit® has grown in popularity throughout the general population from adults to youths but, the safety of CrossFit® has yet to be explored.

There has been documented concerns of safety via the *Consortium for Health and Military Performance and American College of Sports Medicine Consensus Paper on Extreme Conditioning Programs in Military Personnel* (*Consensus Paper*) (11). In relation to this concern, Hak et al. (2013) (26) performed a descriptive study using a questionnaire to gather data about the injuries which occur from CrossFit®. Per their sample, it was determined that 3.1 injuries occur per 1000 hours of training. This injury rate was seen as similar to weightlifting, powerlifting and gymnastics (26). They found that 186 injuries were reported from the 132 responses received. Of the injuries reported, 25.8% were shoulder injuries which was considered higher than the number of shoulder injuries reported for elite and competitive Olympic weightlifters (26). This may be due to the use of heavy resistance, a high number of repetitions and high intensity the CrossFit® program utilizes when performing Olympic lifts (26). In addition, the *Consensus Paper* (11) seemed to place an emphasis on learning about potential injury risks with other ECPs. In particular, a greater understanding of ER and its risk of development when performing ECPs are required (11).

EXERTIONAL RHABDOMYOLYSIS

Rhabdomyolysis is a skeletal muscle injury resulting in the breakdown of muscle tissue and the leakage of muscle cell contents, such as myoglobin and creatine kinase (CK), into the circulatory system disrupting cell homeostasis (8,12,13,27,35,38,45). This conditioning could be triggered by crush injuries, cocaine use, immobilization, alcohol use and exercise though it is not well understood why one patient develops high CK levels or rhabdomyolysis and another does not when they experience the same trigger (9,27). Episodes of rhabdomyolysis that have occurred due to exercise have been termed exercise-induced or exertional rhabdomyolysis (ER).

Exertional rhabdomyolysis typically involves the use of strenuous, excessive or repetitive physical training, usually of the eccentric nature, at an intensity the individual is unprepared for (13,38,45). In addition to the overly physically demanding exercises, a combination of heat stress, dehydration, being untrained, sickle cell trait, the use of certain drugs (statins, anticholingergics, amphetamines, anabolic steroids, glycyrrhizinic acid - present in black licorice), dietary supplements (ephedra and caffeine) or "high stakes training" for firefighters, law enforcement or military cadets may increase the risk of developing ER (13,38). However, incidence of ER has been known to occur in the absence of heat stress and dehydration and in those who are well conditioned, healthy athletes (13).

About 26,000 incidences of rhabdomyolysis are reported annually in the United States with about 47% of those being diagnosed as ER (13,27). Individuals reporting to the hospital with complaints of muscle pain, swelling, weakness and brown (tea or cola-colored) urine after exercise should result in the physician being suspicious of the presence of acute ER (12,27,35,45). There needs to be an increased awareness for acute ER as it is often underdiagnosed (35). This could be costly as ER can result in additional complications. Mild to moderate acute ER can result in electrolyte abnormalities (hyperkalemia, hypernatremia and hyperphosphatemia) (35,45). More serious cases can result in acute myoglobinuria, renal failure, compartment syndrome, cardiac arrhythmia and death in 5% of cases (32,35,38,45). Due to the seriousness of the complications that can arise with ER, diagnosis needs to be accurate, followed by swift treatment.

Diagnosis and Treatment of Exertional Rhabdomyolysis

A physical examination is typically performed with emphasis on looking for swelling, tenderness and tenseness in muscles with pain in the muscles used during the previous exercise stint (35,45). In addition, lab tests for myoglobin and CK levels are performed. A simple dipstick test is performed to identify blood in the urine. Diagnosis should be confirmed by measuring serum CK levels if the dipstick test is positive for myoglobinuria and a microscopic examination of the urine does not show it to contain red blood cells (35). Normal CK ranges for males are 55 to 170 IU/L and females are 30 to 135 IU/L (32). The most used diagnostic criteria for ER involves having the CK levels at least five times the upper limit of normal (38,45). Creatine kinase levels are considered the primary serum marker for ER due to its high sensitivity; however it is not specific (27,32).

This is seen in the lack of consensus on what threshold of CK elevation relates with ER (32). For example, the United States Food and Drug Administration states ER is defined as an individual having CK levels more than 50 times the upper limit of normal or having CK levels of 10000 IU/L along with organ damage that is usually seen as renal compromise (32). The National Lipid Association's Muscle Safety Expert Panel (NLAMSEP) has a different take on what is defined as ER. They state an individual has ER if any evidence of muscle cell destruction is found regardless of the CK levels and the relationship to changes in renal function (32). In addition, this panel also gives categories of CK elevations: mild (<10 times normal levels), moderate (10-49 times normal levels) and marked (greater than or equal to 50 times normal levels (32). ER can be diagnosed with a CK level at least five times greater than the norm, yet that is only categorized as mild according to the NLAMSEP. Regardless of the diagnostic criteria used to determine if a patient has ER, treatment needs to begin immediately.

Treatment typically involves early intravenous (IV) fluid replacement to increase urine production while monitoring CK levels and monitoring for further complications such as compartment syndrome or acute renal failure (35,38). However, there appears to be no established link for normal, healthy individuals who regularly exercise or perform high intensity eccentric exercise acutely with kidney dysfunction or muscle disorder (9). Patients could receive as much as four to ten liters of normal saline to help re-hydrate (35). When monitoring CK levels, there is not an acceptable level the patient must reach before being discharged or an acceptable rate of decreased progression (38). When a patient is discharged, they are advised on correct hydration, rest rates and safety in regards to exercise. They should also be instructed to avoid eccentric exercise and exercising in hot environments (17). It may also be recommended that the patient attend physical therapy in order to recondition gradually and to help facilitate an early return to exercise (17). While specific diagnostic criteria and treatment considerations in regard to CK levels for ER are not well agreed upon and is an area in need of further research (45), most agree that CK levels normally increase with exercise (32).

Creatine Kinase's Association with Exercise and Exertional Rhabdomyolysis

Exercise is known to increase CK levels but especially in males, African Americans and untrained individuals (32). Moderate-intensity exercise (heart rate between 55% and 90% of maximum) has been known to increase CK levels to the threshold for diagnosis of ER (32). The greatest rise in CK levels tends to come from higher-intensity, longer-duration and weight-bearing exercise involving eccentric muscular contractions and downhill running (32). Endurance type exercises also produce less extreme rises in CK levels as compared to eccentric-type exercise (17). For example, eccentric exercises could result in a rise of 10 to 20 times the normal serum CK levels but, non-weight-bearing exercises and those involving fewer eccentric movements, such as swimming and cycling, result in nominal increases in CK levels (32). Other variables that could influence the rise in CK levels include gravitational forces, vibrations, temperature and altitude (32). During exercise and post-exercise there is a rough time table as to how CK levels rise.

Two to 12 hours after exercise, CK levels rise until they reach peak concentrations around three to four days post-exercise (13,17). It is not clear if a rise in CK levels can be compounded from one day to next by exercising multiple days in a row though it would seem possible if the exercise resulted in additional levels of stress seen with muscular soreness; more research would be needed in this area. If an individual presents to the hospital within 24 to 48 hours after strenuous exercise complaining of symptoms leading to the physician being suspicious of ER, then inpatient therapy is highly recommended due to the chance of the patient of developing high CK levels (17). However, if a patient presents to the hospital about three days post-exercise with symptoms of ER but he or she is not dehydrated, has no urine discoloration and no signs of compartment syndrome along with CK levels less than 15000 to 20000 IU/L, then it is possible they have already reached peak CK levels and can be managed as an outpatient with oral hydration and rest (17). With an understanding of the working of CK levels and the development of ER from exercise, practical examples can be applied.

Case Studies involving Exertional Rhabdomyolysis

From July 1971 to July 1972, 3.2 cases per 1000 recruits were reported to experience acute ER at the Marine Corps Recruit Depot in Parris Island, South Carolina (15). More recently, Smoot et al (45) reported that in civilian populations and military personnel, rates of ER range from 2 per 10000 persons and 2.2 to 8 per 10000 persons, respectively, though most are reported in single cases (45). The first case study from Inklebarger et al. (29) was on a 63 year old female, recreational athlete. She presented to the hospital with lower back pain, leg pain and stiffness after stationary bicycling one day prior. Inklebarger et al. (29) describes the patient as having a history of lower back pain and sciatica due to a prior year-long disability along with a family history of hypertension and non-insulin diabetes leading her to seek a more active lifestyle and being referred for exercise prescription. The subject also described having immediate onset of pain and weakness in both of her thighs post exercise. The symptoms felt different from her normal baseline of pain. After checking her vital signs and urine, both were unremarkable and she was discharged. The subject returned the next day with worsening leg pain and dark urine. While the urinalysis remained negative, CK levels were at 38,120 IU/L. The patient was then admitted for oral and IV hydration along with fluid balance monitoring. After CK levels rapidly normalized, the subject was discharged two days later (29).

Line and Rust (35) described a case study about a 32 year old physician who was used to running 30 miles per week. In this case, he was running in a marathon on a warm day (85°F/29°C) and after about nine miles, collapsed due to severe pain in his calves and thighs. He was hospitalized with his CK levels peaking at 108,000 IU/L. More severe complications arose and he required dialysis therapy and treatment for compartment compression syndrome in his thighs and calves. He eventually made a full recovery after six months (35).

Line and Rust (35) reported another case study describing a 24 year old man who had completed a two hour, high-intensity weight lifting session with heavy weights two days before visiting the hospital. He came to the hospital complaining of pain and bilateral swelling in his arms and chest. The physical exam revealed bilateral swelling, tenderness and tenseness of the pectoralis, biceps and triceps muscles. His urinalysis was normal except for 3+ positive heme but under microscopic examination, the urine was negative for red blood cells. His CK levels were 13,758 IU/L and so he was admitted to the hospital and vigorously hydrated. The CK levels peaked at 50,200 IU/l before slowly returning to normal over the following six days. During this time he had no overt bleeding and normal renal function and, he was able to successfully recover (35).

The next case study was not on a single person but on a single sports team, specifically the University of Iowa football team (45). After playing in their bowl game on December 28, 2010, they took a three week break. The team then participated in their first off-season workouts on January 20, 21 and 24, 2011. The first workout consisted of sled pushes and several weight lifting tasks such as performing a timed, 100 repetitions of back squats at 50% of their one repetition maximum. For the back squats, the players were allowed to take as much time and use as many sets as they needed to complete the task. Three players presented to the athletic training staff with having three days of dark urine, severe muscle soreness and muscle swelling. They also had antalgic gaits, tender, swollen lower extremity muscles and normal neurovascular examinations. Smoot et al. (45) reported these three players as having CK levels ranging from 166,991 to 233,167 IU/L. After a fourth player reported to an athletic trainer with similar symptoms, the medical staff sent out a mass text to all players urging them to report to medical staff immediately if they experienced any of the symptoms of ER. Nine additional players responded to the text and all were admitted to the hospital. Of the 13 players who developed ER, 10 allowed Smoot et al (45) to review their medical records.

These players had CK levels ranging from 96,987 to 331,044 IU/L, normal electrolyte levels and had positive urinalyses but red blood cells were not seen under microscopic examination. One of the 10 subjects tested positive for opiates, but that was due to the player receiving narcotics for pain previous to the urine sample being collected. The other nine drug tests were negative. One player had the sickle cell trait but the others did not. Treatment involved IV fluids in order to produce 200 to 300 mL/h of urine output. After 24 hours, CK levels started to drop back down. All players were discharged four to six days after being admitted when myoglobinuria had resolved and their CK levels were about 10,000 IU/L. No one required hemodialysis or acquired compartment syndrome. After two weeks of being discharged, all subjects were asymptomatic and had CK levels between 100 to 700 IU/L. The athletes began to gradually return to practice 14 to 24 days post-hospitalization. It was determined by the authors (45) that the longer the player needed to complete 100 repetitions of back squats the higher the individual's risk was to develop ER. Due to this insight, the 100 repetitions of back squats task was removed from future workout plans by the coaching staff (45).

This next case study comes from a patient's own personal account with ER as posted on the subject's blog (36). This is purely the patient's own telling of the events that occurred and is in no way a peer-reviewed article. Lombardi (36) considered himself an athlete as he played multiple high school sports and was recently playing basketball once a week, along with being in an intramural soccer league and two intramural softball leagues. The subject went on to launch his own start-up business and started to spend about 16 hours at his computer (36). This may mean he was becoming more sedentary. Lombardi (36) gained weight, increasing from about 79.38 kg to 88.45 kg (height, 185.42 cm). In order to get back into shape he planned to perform P90X®. On the first day, he completed the first half of the first workout involving chest and back exercises (push-ups and pull-ups). The next day, he noted feeling very sore and as the day went on, he noticed swelling in his triceps, deltoids and pectorals. He still decided to perform the day two P90X® workout which was more leg focused. On the third day, he describes muscular pain which made it difficult for him to move. He decided he needed to take a break from P90X®. The fourth day he noticed his urine was cola-colored and decided to visit a kidney specialist who eventually sent him to the hospital on suspicions of ER. At the hospital he was given 200 mL of IV fluids. On the fifth day, he was admitted to the hospital as his urine contained blood and myoglobin. The subject's CK levels were over 16,800 IU/L (that was the maximum value the machine could go up to for that specific test for that hospital). The kidney specialist determined his CK levels to be over 50,000 IU/L which was the maximum value the specialist's machine could detect. The subject was then given two bags of IV fluids (the amount is unknown) and a catheter in hopes of preventing kidney failure. His liver enzymes were reported as high on the sixth day. He was ordered an ultrasound and MRI on the organ but the results of the tests were unknown to the patient when he reported his experience. On the seventh day, CK levels fell to 12,000 IU/L and the patient was discharged from the hospital. He was told to stay hydrated and follow up on the liver examination. In addition, he was told to not exercise for a few weeks and to ease back into sports after resting (36). This reported experience could still be considered as a good example of how ER can come with additional complications when the individual is not aware of the signals his or her body is implying and so results in delaying treatment.

In following with ECPs and ER, this case study involves a 33 year old law enforcement officer who was previously healthy and physically fit before needing hospitalization (25). He reported to the hospital three days after completing a high intensity CrossFit® workout with feelings of fatigue, muscle soreness and swelling. He described the CrossFit® exercise program as prolonged and extreme; and feeling fatigued, short of breath, muscularly weak and having sleep disturbances after completion of the workout. He also reported to having completed five days of exercise previous to the start of his CrossFit® program. The physical examination revealed muscle tenderness to light palpation, bicep and tricep compartment swelling and pectoralis muscle swelling along with difficulty performing full elbow flexion and extension due to pain. A urinalysis came back positive for blood but microscopic examination revealed no red blood cells were present and a blood test revealed CK levels of 26,000 IU/L. He was then diagnosed with ER and admitted to the hospital. There he was treated with IV fluids and had CK levels and muscle soreness monitored. He was discharged six days later with a CK level of 995 IU/L. He was able to return to high intensity training after four months of mild to moderate aerobic training along with instructions for high intensity workout recovery and proper hydration (25). While CrossFit® was performed leading up to this subject being diagnosed with ER, it is not clear if ER was a direct result of CrossFit® or the compounding effect of CrossFit® and the five previous days of exercise.

CrossFit® does acknowledge five people who have developed ER associated with their program (21). They have even documented these cases. There are very few details as this was not a peer-reviewed case study article. The article described the “victims” as all needing hospitalization, with the longest stay being six days and the shortest being two days (21). All of the subjects also made full recoveries. The first individual described was a female college student in her early twenties who also surfed and mountain-biked. She attended her second-ever CrossFit® workout within three days of the first one. This workout was described as a hard-hitting, fast-moving group workout including high repetition assisted pull-ups. It seems she became sore and then sorer and decided to go to the hospital where she was admitted for three days but, it was reported, that she “didn’t feel sick” (21).

The second subject was a dermatologist in his late forties as well as an avid tennis player. He attended his first CrossFit® workout on a Monday and his second on Wednesday. He followed that up with playing multiple hours of tennis on Friday, Saturday and Sunday. That next Monday he reported to the hospital with his major complaint being soreness.

The next subject was described as a female collegiate softball pitcher who had challenged the “manhood” of her football running back boyfriend after he complained about the CrossFit® workout called “Tabata This” (21). The boyfriend then challenged her to complete the “Pepsi” challenge which she did not and resulted in her being hospitalized for four days after presenting to the hospital three days post-exercise (21). She was described by the author as being a “very sick girl” (21).

The fourth person was described as being male and special operations personnel. It seems he was also a bodybuilder and runner who chose to ignore warnings to “learn something” about CrossFit® before participating in a three day CrossFit® seminar (21). On his first two days, he was described to have had suffered third and fourth quartile outputs resulting in him needing to not participate in the workout on the third day. He was then hospitalized on days four through eight. The article states that having to sit out on the third day may have "saved his life" and that he had had "way too much CrossFit® way too soon" (21).

Lastly, was a middle-age male who was a fit SWAT officer. A friend took him through a "Helen"-like workout on his first day (21). It is described that this workout, "almost killed him – literally. Our first and worst bout of Rhabdo. Now an avid CrossFitter" (21). It was reported that each of these individuals were new to CrossFit® and developed ER in their first or second workouts. Those who were able to perform a second workout had performed it at least two days after the first workout. They seem to have continued on with CrossFit® as their training program. Lastly, Glassman (21) states that they have never had an experienced "CrossFitter" develop ER.

Summary of the Case Studies

In summary of the peer-reviewed case studies, all four describe the subjects as having muscular pain and/or swelling along with urinalysis that was positive for blood but had no red blood cells present and what are considered high CK levels (25,29,35,45). Two reported complaints of dark urine (29,45). They all stated that subjects were treated with IV fluids and monitored further (25,29,35,45) with only one patient needing additional treatment due to compartment compression syndrome and renal complications (35). They were all discharged after being hospitalized for a range of two to six days and they all made full recoveries within six months (25,29,35,45).

In addition to these case studies, another incident was reported by the patient on their blog and the other incidents were depicted by CrossFit® (21,36). Both articles described similar findings to those of the case studies with the exception that CrossFit® was unable to report results of blood test, urinalyses and if they were actually medically diagnosed with ER (21,36). The CrossFit® article states that they have yet to hear about ER cases involving sedentary or inactive individuals (21) and with this article being written in 2005 it's very possible that that is true, considering the closest to a sedentary or inactive individual in the previous cases comes from Lombardi (36) who describes his own experiences for everyone to see in 2013. He describes himself to having started spending roughly 16 hours sitting in front of a computer seven days a week and gaining enough weight to go from 79.38 kg to 88.45 kg (36). He could be considered to be an individual who has started to fall into an inactive state after being an active individual previously. One could also consider the 63 year old female who developed ER from stationary biking. Her family history of hypertension and non-insulin diabetes led to seeking a more active lifestyle and being prescribed exercise (29). However, it is unknown as to how far she was into her exercise prescription. Though unclear, it is possible this subject may have also been on the more inactive side of the spectrum of activity. Though, again, this published article was written in 2010, five years after the CrossFit® article. This may mean CrossFit® needs to reevaluate the literature and update their stance on ER.

CROSSFIT'S® DEFFENSE AGAINST DEVELOPING EXERTIONAL RHABDOMYOLYSIS

CrossFit® (23) states that their program is designed to defend against ER. This is because workouts last 20 minutes or less. The tendency for CrossFit® to change the metabolic pathways being used over the duration of the workout results in lessening the effects of lactic acid as anaerobic exercise produces lactic acid and aerobic exercise absorbs lactic acid (23). However, as participants are supposed to be performing at their personal best during every workout, it is unclear how participants could avoid anaerobic levels while performing maximal exercise. CrossFit® also advocates gradual conditioning by encouraging the individual to safely challenge themselves during each workout (23) though there is not an explanation given on how the progression should occur. With normal hydration before the workout and the individualization of the CrossFit® program for each person to perform their personal best lessens the risk of developing ER.

The individualization seems to come from the participant controlling the intensity of the workout and each individual is encouraged to adjust loads or substitute workouts to their capabilities. CrossFit® claims their participants are also not susceptible to overexertion due to group training as all athletes are not held to the same standard of work production or power output (23). Yet in the *CrossFit® Induced Rhabdo* (21) released by CrossFit®, it states that one of the "victims" had participated in a group workout that possibly resulted in her hospitalization. Therefore, there seems to be some discrepancy as to whether CrossFit® does or does not require group workouts at some point in their training program.

Lastly, as part of CrossFit's® consent and release form individuals are made aware that it is their responsibility to know their own body's limitations while exercising. They are responsible for setting their own level of exertion and are not to exceed this limit which would put them at risk for developing injuries (i.e. ER) (23). This type of policy seems to make the assumption that the average CrossFit® participant has this type of knowledge. While it would be an acceptable assumption for a highly trained athlete coming into CrossFit®, a novice should not be expected to have this sort of understanding about his or her body. This could also call into question the role of the CrossFit® trainer. Even though the participant is responsible for his or her workout, the trainer should still be actively assisting, supervising and have the upmost authority to tell the participant he or she needs to stop if/when a breakdown in movement technique or fatigue compromising the participant's judgment is observed.

CONCLUSION

It should be understood that the incidence of ER in the United States (13,27). However, ER clearly has the occasional occurrence in CrossFit® (as well as other ECPs) as seen by their own report on the few cases they have had (21). The issue of developing ER during CrossFit® has even caught the attention of the media (41,48) but the actual incidence rate for developing ER from CrossFit® is unknown (although most likely minimal). This could be further assured if the participant has a good understanding of his or her limits and is taught by a highly qualified and well-practiced CrossFit® trainer, it could be highly possibly to have very little risk of developing ER. It is interesting however, that ER seemed to be a largely unknown condition prior to CrossFit®, and other ECPs, catching on with the general population. Therefore, additional research is clearly needed to gain a better understanding of the CrossFit® program's effects on the development of ER.

Additionally, how CK levels rise due to CrossFit® could be explored and compared to other more traditional sports (i.e. weightlifting, football, triathlon, etc.). Due to the variation at which CK levels can be at when ER develops, it may be more appropriate to analyze CK levels for the various CrossFit® WODs available. Examples of the differing values of CK levels can be seen in the different CK levels reported in the previous case studies mentioned. The range was 13,758 – 331,044 IU/L (35,45) from subjects of varying exercise backgrounds which could be a similar background for the CrossFit® population. Analyzing the CrossFit® WODs may enable researchers to determine which WODs are the most taxing for the skeletal muscle. It may be possible to use the National Lipid Association's Muscle Safety Expert Panel's categories of CK elevations (32) to help rank WODs from least to most taxing. This would allow for further determination of the safety of CrossFit®.

From the current literature available it is clear researchers have only just begun their investigation of CrossFit® and other ECPs. Due to ECPs program prescription avoiding the use of appropriate and safe exercise prescriptions set by the ACSM (33), it is important to consult a physician to make sure you are physically prepared to handle the high demands of the program. As additional research on ECP's effectiveness and safety is conducted, physicians could be able to explain to their patients how to safely manage themselves in exercise programs of this intensity. This could possibly decrease the potential for muscle strains, ligament damage and potentially life threatening muscular injuries such as ER. The way people exercise is rapidly changing, placing emphasis on the importance of up-to-date research in order to ensure that the most effective and productive exercise regiments are being put into practice.

CHAPTER 3: CONCLUSIONS AND RECOMMENDATIONS

PRACTICAL APPLICATIONS

From this sample, there was one reported case of ER from a CrossFit® participant; therefore, ER does have the rare occurrence in CrossFit®. However, CrossFit's® highly intense bouts seem to have exercisers reporting greater RPEs and hard days per week vs. ACSM training routines. Therefore, participants of CrossFit® should strive to maintain a good understanding of their limitations during exercise in order to cope with demanding intensity and repetitive exercise bouts. Furthermore, all exercisers engaged in highly intense exercise should hydrate appropriately prior to exertion, and seek highly qualified and experienced CrossFit® or strength and conditioning professionals. Ultimately, exercise and training programs are ever changing, placing an emphasis on the importance of up-to-date research in order to ensure that the most effective, productive, and safe exercise regiments be put into practice.

FUTURE RESEARCH CONSIDERATIONS

Areas future researchers should consider are the changes in CK levels during CrossFit®; in particular, the CK levels produced during each CrossFit® WOD. The list of CrossFit® WODs with at least an RPE of five provides a good start. The CK levels of those WODs could yield additional insights into the risk they yield for ER development via the National Lipid Association's Muscle Safety Expert Panel's categories of CK elevations (32). Overall changes in

CK levels during CrossFit® could also be compared to traditional sports (i.e. weightlifting, football, triathlon, etc.).

Lastly, utilizing similar methods from this study could help explore other ECPs (Insanity® and P90X®). This could result in a greater understanding of these extreme exercise programs in terms of overall intensity, the intensity of specific workouts and identification of primary risk factors for ER development in those programs. More importantly, it could shed light on the overall incidence of ER for ECPs.

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APPENDIX A

A PERFORMANCE PROFILE RELATED TO BUILDING ELITE FITNESS IN MALE COMPETITORS

ABSTRACT

The feats of the best CrossFit® athletes are showcased in the CrossFit® Games. Currently fitness benchmarks have yet to be summarized to determine a profile of CrossFit® Games athletes. The purpose of this study was to determine a performance profile of the 2013 male CrossFit® Games athletes using available fitness data. The top 30 participants were split into the top 10 (T10), middle 10 (M10) and bottom 10 (B10) competitors in order to stratify comparisons between accomplished athletes. Seven documented, traditional fitness benchmarks were analyzed for each group and included: clean and jerk, snatch, deadlift, back squat, 400 m sprint, 5 k run and max number of pull-ups. These benchmarks were also divided into aerobic (5K run and max pull-ups) or anaerobic (all others) categories. A one way ANOVA and independent T-Test comparisons ($p \leq 0.007$) between groups were employed. For each group the number of tests they performed highest in (vs. the other groups) was depicted as a percent. No significant difference was found among the groups for any benchmark. However, the T10 bested 57.14%, M10 28.57% and B10 14.29% of the seven benchmarks. Interestingly, B10 surpassed M10 (but not T10) in 71.43% of the benchmarks. Of the fitness tests T10 won out, 75% were anaerobic and 25% were aerobic. For M10, 50% were anaerobic and 50% were aerobic. The only benchmark B10 won out was an anaerobic test (i.e., 400 m sprint time). If a participant's aim is to finish in the top 10 at the CrossFit® Games, then it would seem best to focus on improving maximums for the anaerobic benchmarks mentioned above while sacrificing aerobic training.

KEY WORDS: CrossFit, Crossfit Games, fitness benchmarks

INTRODUCTION

CrossFit® is becoming a vastly popular strength and conditioning program by embracing a "fitness as sport" view (18,37,42). They aim to forge elite fitness through their three fitness standards. The first is increasing the competence of the athlete in the ten general physical skills: cardiovascular/respiratory endurance, stamina, strength, flexibility, power, coordination, agility, balance and accuracy. The second standard aims to have the athlete perform well at any and every task by maintaining a broad and constantly varied training stimulus. The last standard aims to promote total fitness by training in all three of the metabolic pathways, phosphagen, glycolytic and oxidative (19). Through these three standards, CrossFit® advocates the development of fitness by creating workouts which are purposely broad, general and inclusive. This can be seen in their definition of world-class fitness:

"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 and jerks, 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 (19)"

Based on this definition, it is easy to see why CrossFit® has become so popular with the general population. CrossFit® would be attractive to any athlete with any background because of how broad and inclusive their program is.

The base of the CrossFit® program is built from functional movements. CrossFit® defines functional movements as those which recruit motor patterns in waves of contraction from core to extremity. These movements are multi-joint, requiring the body to move or move an object efficiently and effectively (20). CrossFit® selects the functional movements for their program based on, "range of joint motion, uniqueness of line of action, length of line of action, strength of line of action, commonness of motor pattern, demands on flexibility, irreducibility, utility, foundational value, neurological value, measurable impact on adherents, and, potential for metabolically induced discomfort" (20). Through these movements CrossFit® seeks to improve maximal oxygen consumption without the loss of strength, speed and power. Therefore, they created varied and broad workouts which are meant to be performed at a high intensity using mainly anaerobic efforts and intervals while avoiding the mastery of single modalities (19).

These workouts have been described as requiring to lift heavy loads and utilize high intensities with short rest periods resulting in high heart rates (22). Diving further into the CrossFit® program design, CrossFit® created a template called the “functional couplet.” This term refers to simply pairing two functional movements, usually one is a classic weightlifting move such as the deadlift and the other in a classic gymnastic or calisthenics move such as the handstand push-up (20). It may then be required for the athlete to perform a set number of rounds (generally three to five) of the couplet for best time or to perform as many rounds in a set amount of time (usually no longer than 20 minutes). As these types of workouts are to be performed at very high intensities, this requires a second template set up called the “focus day” (20). There are three different types of “focus days,” one consists of a distance effort, the second consists of developing a gymnastics skill and the third consists of single repetition efforts on a basic lift or focusing on correct technique. A cycle would then be as follows: couplet, focus, couplet, off. All of the workouts are performed on average at a high intensity with the repetitions, sets, combinations of exercises and the length of the workout varying (20). Table 36 provides an example of a 16 day cycle.

Through their program, based strongly in performance of functional movements at high intensity with constantly varied and broad structure, CrossFit® firmly believes: their program is essential to health and fitness, is comprised of only safe protocols, is the most effective in rehabilitating from injury, is unique in developing core strength, elicits an inordinate neuroendocrine response, produces superior cardiorespiratory adaptations and yields unparalleled general physical preparedness or fitness (20). CrossFit’s® belief seems to be backed by evidence based on their athletes improvement results from the workouts alone (20).

In relation to the 2013 CrossFit® Games, it would seem that those who finished higher overall would then perform better in traditional fitness benchmarks. Currently traditional benchmarks of fitness have yet to be summarized to determine a profile of CrossFit® Games athletes. Therefore, the purpose of this article shall be to explore a possible performance profile of the 2013 male CrossFit® Games athletes based on available fitness data.

METHODS

Experimental Approach to the Problem

The objective will be to determine which/if any of the seven traditional benchmarks relates to placement in the top 10 (T10), middle 10 (M10) or bottom 10 (B10) of the 2013 CrossFit® Games. This stratification will allow comparisons between accomplished athletes. The seven fitness benchmarks were: clean and jerk, snatch, deadlift, back squat, 400 m sprint, 5 k run and maximum number of pull-ups. Performances of these benchmarks will be examined to see if any of the groups perform better than another (i.e. T10 bests M10 and B10 in the snatch) by use of significant differences of the means. The analysis will be used to determine a performance profile for future participants of the CrossFit® Games who wish to better their pervious performance or perform well for the first timers.

Subjects

The top 30 male finishers (mean ± SD: age - 26.8 ± 3.32 yrs., n = 30; height - 177.63 ± 6.4 cm, n = 28; weight - 88.78 ± 6.22 kg, n = 30) were selected from the 2013 CrossFit® Games for analysis as the top 30 participate in every event. The rest of the participants were cut from the games based on points earned after the first 10 events. Participants were gathered via the CrossFit® Games website (5) as well as data for their performances in the seven traditional fitness benchmarks, age, weight, and height (Tables 37 and 38). Unfortunately, not every athlete who participated in the 2013 CrossFit® Games had a short biography with their benchmarks listed.

Procedures

The fitness benchmarks were divided into aerobic (5 k run and max pull-ups) or anaerobic (all others) categories. For each group, the number of tests they performed highest in (vs. the other groups) was depicted as a percent. Since data were collected from a public and freely accessible internet source, IRB approve was not required. All of the data listed were in the English system on the CrossFit® Games website (5), so height was converted from feet and inches to centimeters to the nearest hundredth and pounds was converted to kilograms to the nearest hundredth. Times reported were in hours, minutes and seconds and were converted to seconds to the nearest tenth. Data were then entered into statistical software.

Statistical Analysis

To perform comparisons between groups, one way ANOVAs and independent T-Test comparisons were done via IBM SPSS Statistics 21. As multiple comparisons were being made using the same groups, the experimentwise error rate was increased. In order to account for this, alpha will be significant at $p \leq 0.007$ (0.005 ÷ 7) but an upper limit of alpha will be listed as $p \leq 0.30$. It should therefore be kept in mind that this was exploratory research, as a performance profile involving participants from the 2013 CrossFit® Games was the first of its kind. In addition, very little research had been conducted on CrossFit® participants in general especially when it came to physiological or performance profiles.

Bivariate and partial correlations (Tables 39 and 40, respectively) were run to determine if the groupings (T10, M10 and B10) alter the relationship among the benchmark variables. The grouping should not be considered when it comes to relationships between clean and jerk verse snatch, clean and jerk verse back squat, clean and jerk verse 400 m sprint, clean and jerk verse 5 k run, snatch verse max pull-ups, snatch verse 400 m sprint, snatch verse 5 k run, deadlift verse max pull-ups, deadlift verse 5 k run, back squat verse max pull-up, 400 m sprint verse 5 k run. This was because the r values did not differ by at least 0.10 when comparing a bivariate correlation and a partial correlation controlling for the grouping. The groupings should be considered when it comes to relationships between clean and jerk verse deadlift, clean and jerk verse max pull-ups, snatch verse deadlift, snatch verse back squat, deadlift verse back squat, deadlift verse 400 m sprint, back squat verse 400 m sprint, back squat verse 5 k run, max pull-ups verse 400 m sprint, max pull-up verse 5 k run, as the r values differed by 0.10 when comparing a bivariate correlation and a partial correlation controlling for the grouping.

RESULTS

Multiple one-way ANOVAs were used for these variables: snatch, deadlift, back squat, 400 m sprint, 5 k run and maximum number of pull-ups. As the skewedness for each variable was below 2.58, a normal distribution can be assumed. When using the Levene Statistic ($p \leq 0.05$), the significance was $p > 0.05$ for each of these variables so a homogeneity of variance can be assumed. The mean for the snatch was 120.50 kg with a standard deviation of 8.70 kg ($n = 24$). The mean for the deadlift was 231.08 kg with a standard deviation of 13.04 kg ($n = 22$). The mean for the back squat was 199.60 kg with a standard deviation of 15.33 kg ($n = 23$). The mean for the maximum number of pull-ups was 57.22 pull-ups with a standard deviation of 11.27 pull-ups ($n = 18$). The mean for the 400 m sprint was 58.19 s with a standard deviation of 5.59 s ($n = 16$). The mean for the 5 k run was 1206.63 s with a standard deviation of 93.34 s ($n = 24$).

Using a one-way ANOVA ($p \leq 0.007$), for the maximum number of pull-ups ($n = 18$) the degrees of freedom between groups was 2 and within groups was 15. A significance was not found as $F(2, 15) = 4.32$, $p = 0.033$, as seen in Table 41. Using a one-way ANOVA ($p \leq 0.007$), for the snatch ($n = 24$) the degrees of freedom between groups was 2 and within groups was 21. A significance was not found as $F(2, 21) = 3.324$, $p = 0.056$, as seen in Table 42. Using a one-way ANOVA ($p \leq 0.007$), for the deadlift ($n = 22$) the degrees of freedom between groups was 2 and within groups was 19. A significance was not found as $F(2, 19) = 2.196$, $p = 0.139$, as seen in Table 43. Using a one-way ANOVA ($p \leq 0.007$), for the back squat ($n = 23$) the degrees of freedom between groups was 2 and within groups was 20. A significance was not found as F (2,

20) = 0.484, p = 0.623, as seen in Table 44. Using a one-way ANOVA ($p \leq 0.007$), for the 400 m sprint (n = 16) the degrees of freedom between groups was 2 and within groups was 13. A significance was not found as F (2, 13) = 0.165, p = 0.850, as seen in Table 45. Using a one-way ANOVA ($p \leq 0.007$), for the 5 k run (n = 16) the degrees of freedom between groups was 2 and within groups was 13. A significance was not found as F (2, 13) = 0.281, p = 0.760, as seen in Table 46.

The clean & jerk had to be analyzed via independent T-Tests as the Levene Statistic ($p \leq 0.05$) was significant, p = 0.035 when using a one-way ANOVA. The skewedness was below 2.58, so a normal distribution is assumed. The mean for the clean and jerk was 146.26 kg with a standard deviation of 9.39 kg. Using an Independent T-Test ($p \leq 0.007$) for comparing T10 and M10, the Levene Statistic ($p \leq 0.05$) was p = 0.398, so homogeneity of variance was assumed. The degree of freedom was 15 and t(15) = 1.463, p = 0.164 was not significant with a mean difference of 5.56 kg and a standard error of difference of 3.80, as seen in Table 47. Using an Independent T-Test ($p \leq 0.007$) for comparing T10 and B10, the Levene Statistic ($p \leq 0.05$) was p = 0.135, so homogeneity of variance was assumed. The degree of freedom was 11 and t(11) = 0.410, p = 0.690 was not significant with a mean difference of 2.62 kg and a standard error of difference of 6.41, as seen in Table 48. Using an Independent T-Test ($p \leq 0.007$) for comparing M10 and B10, the Levene Statistic ($p \leq 0.05$) was p = 0.006, so homogeneity of variance was not assumed. The degree of freedom was 6.301 and t(6.301) = -0.499, p = 0.635 was not significant with a mean difference of 2.93 kg and a standard error of difference of 5.88, as seen in Table 49.

Table 50 shows the ratings of performance for the fitness benchmarks between T10, M10 and B10 based on benchmark means. This table shows that T10 bested 57.14%, M10 28.57% and B10 14.29% of the seven benchmarks. Interestingly, B10 surpassed M10 (but not T10) in 71.43% of the benchmarks. Ultimately, of the fitness tests T10 won out, 75% were anaerobic and 25% were aerobic. For M10, 50% were anaerobic and 50% were aerobic. The only benchmark B10 won out was the 400 m sprint; an anaerobic test.

DISCUSSION

As demonstrated by the results, there was no significant difference between groups. It could be possible that the lack of significant differences between groups, for each variable may be due in part to the nature of CrossFit®. CrossFit's® varied and broad ranges of exercise may result in the closeness of scores for each benchmark between the groups (18). In addition, CrossFit's® program is able to create improvements across all energy systems as demonstrated by Jeffery (30); meaning participants received an improved anaerobic and aerobic capacity. Another possible explanation may be the nature of the CrossFit® Games themselves.

In the games, there were a set number of events competitors must face. In the 2013 CrossFit® Games, the top 30 participants completed 12 events. In each event, competitors were ranked based on their finish compared to other competitors (e.g., first, second, and third). Points were then awarded based on their rank in each event (e.g., first place = 100 points, second = 95 points, and third = 90 points) (5). Therefore, it was possible to do poorly in a couple of events and then make up points in events which a participant was "stronger" in. For example, the 2013 CrossFit® Games winner finished 30^{th} in first event and then tied for 18^{th} in the fifth event. However in the other 10 events, the winner finished in 8^{th} or higher; of those 10 he took first place in the last three events (5). In addition, the second place winner of the CrossFit® Games placed 13^{th}, 43^{rd} and 27^{th} in the first, fifth and sixth events respectively, but then placed 9^{th} or higher in the other nine events with three of those events being first place finishes (5). It would seem then that a future participant may be able to sacrifice training in one aspect of CrossFit® over others and possibly be able to place in the top 10 in future CrossFit® Games.

PRACTICAL APPLICATION

A future participant of the CrossFit® Games seeking to take advantage of the CrossFit® program in order to finish in the top 10 may look to focus more on the strength based exercises during workouts of the day. As shown in Table 50, T10 finishers of the 2013 CrossFit® Games were rated highest in the clean and jerk, snatch, deadlift and maximum number of pull-ups. It is interesting to note that in both running based benchmarks, 400 m sprint and 5 k run; T10 finishers were rated in the middle, behind B10 and M10 respectively. Overall, it would seem that it may be best to focus on improving maximums for the anaerobic benchmarks mentioned in Table 50 while sacrificing aerobic training when aiming to finish in the top 10 in future CrossFit® Games. While maximum numbers of pull-ups were classified as aerobic due to the large number of pull-ups being completed, the time it took to complete the number of pull-ups was not recorded and so was conservatively labeled aerobic. This may be a consideration for future research as CrossFit® tends to use more of a faster, kipping pull-up versus a slower, stricter pull-up (22).

Other considerations may be to determine what is holding B10 finishers back from finishing M10 when B10 was rated ahead of M10 in 71.43% of the traditional fitness benchmarks. In addition, how M10 was still beating out B10 in the 2013 CrossFit® Games when they are rated lower than B10 in majority of the benchmarks. There may be some other variable(s) at work such as time to fatigue or time to recover. Lastly, to perform a similar experimental design described using the 2013 female CrossFit® Games competitors.

APPENDIX B

TABLES AND FIGURES

Table 1: Descriptive statistics on the CrossFit® and ACSM groups for age, height, weight, the number of weeks completed in the respective exercise program, the average RPE and the perceived number of hard days performed in a week. (pg. 5)

CrossFit® group n = 101 ACSM group n = 56			
	Exercise Program	**Mean**	**Standard Deviation**
Age	CrossFit®	34.50	8.74
	ACSM	35.41	10.15
Weight	CrossFit®	79.10	15.83
	ACSM	75.19	27.25
Height	CrossFit®	1.74	0.10
	ACSM	1.71	0.11
Weeks Completed in Program	CrossFit®	7.81	0.85
	ACSM	6.38	2.50
Ave. RPE	CrossFit®	7.29	1.74
	ACSM	5.52	1.35
Hard Days Performed in a Week	CrossFit®	3.99	1.07
	ACSM	3.55	1.39

Table 2: Independent t-test comparing weeks completed in the respective exercise program, average RPE for the program and the number of hard days completed in a week for the Crossfit® and ACSM groups. (pg. 7)

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**
Weeks Completed in Program	Equal variances assumed	147.764	<0.001	5.27	155	<0.001	1.44	0.27
	Equal variances not assumed			4.18	62.07	<0.001	1.44	0.34
Ave. RPE	Equal variances assumed	5.888	0.016	6.59	155	<0.001	1.77	0.29
	Equal variances not assumed			7.08	138.50	<0.001	1.77	0.25
Number of Hard Days in a Week	Equal variances assumed	8.211	0.005	2.20	155	0.030	0.44	0.20
	Equal variances not assumed			2.04	91.93	0.044	0.44	0.21

Table 3: Chi-square analysis via crosstabulation about whether participants had prior exercise experience before starting their current exercise program. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Prior Exercise Experience	**Yes**	Count	80	52	132
		Expected Count	84.9	47.1	132.0
		% within Prior Exer.	60.6%	39.4%	100.0%
		% within Exer. Program	79.2%	92.9%	84.1%
		% of Total	51.0%	33.1%	84.1%
	No	Count	21	4	25
		Expected Count	16.1	8.9	25.0
		% within Prior Exer.	84.0%	16.0%	100.0%
		% within Exer. Program	20.8%	7.1%	15.9%
		% of Total	13.4%	2.5%	15.9%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Prior Exer.	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	5.013	1	0.025

Table 4: Chi-square analysis via crosstabulation about whether participants warm-up prior to starting their workout. (pg. 7)

			Exercise Program		**Total**
			CrossFit	**ACSM**	
Warm-up	**Yes**	Count	98	52	132
		Expected Count	96.5	53.3	132.0
		% within Warm-up	65.3%	34.7%	100.0%
		% within Exer. Program	97.0%	92.9%	95.5%
		% of Total	62.4%	33.1%	95.5%
	No	Count	3	4	7
		Expected Count	4.5	2.5	7.0
		% within Warm-up	42.9%	57.1%	100.0%
		% within Exer. Program	3.0%	7.1%	4.5%
		% of Total	1.9%	2.5%	4.5%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Warm-up	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	1.472	1	0.225

Table 5: Chi-square analysis via crosstabulation whether aspirin was regularly taken by participants in their respective exercise program. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Aspirin	**Yes**	Count	12	4	16
		Expected Count	10.3	5.7	16.0
		% within Aspirin	75.0%	25.0%	100.0%
		% within Exer. Program	11.9%	7.1%	10.2%
		% of Total	7.6%	2.5%	10.2%
	No	Count	89	52	141
		Expected Count	90.7	50.3	141.0
		% within Aspirin	63.1%	36.9%	100.0%
		% within Exer. Program	88.1%	92.9%	89.8%
		% of Total	56.7%	33.1%	89.8%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Aspirin	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	0.884	1	0.347

Table 6: Chi-square analysis via crosstabulation whether anti-cholinergic agents were regularly taken by participants in their respective exercise program. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Anti-Cholinergic Agents	**Yes**	Count	0	1	1
		Expected Count	0.6	0.4	1.0
		% within Anti-Cholinergic Agents	0.0%	100%	100%
		% within Exer. Program	0.0%	1.8%	0.6%
		% of Total	0.0%	0.6%	0.6%
	No	Count	101	55	156
		Expected Count	100.4	55.6	156.0
		% within Anti-Cholinergic Agents	64.7%	35.3%	100.0%
		% within Exer. Program	100.0%	98.2%	99.4%
		% of Total	64.3%	35.0%	99.4%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Anti-Cholinergic Agents	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-square	1.815	1	0.178

Table 7: Chi-square analysis via crosstabulation whether statins were regularly taken by participants in their respective exercise program. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Statins	**Yes**	Count	0	2	2
		Expected Count	1.3	0.7	2.0
		% within Statins	0.0%	100%	100%
		% within Exer. Program	0.0%	1.8%	0.6%
		% of Total	0.0%	0.6%	0.6%
	No	Count	101	54	155
		Expected Count	99.7	55.3	155.0
		% within Statins	65.2%	34.8%	100.0%
		% within Exer. Program	100.0%	96.4%	98.7%
		% of Total	64.3%	34.4%	98.7%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Statins	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	3.654	1	0.056

Table 8: Chi-square analysis via crosstabulation whether other medications were regularly taken by participants in their respective exercise program. (pg. 7)

			Exercise Program		**Total**
			CrossFit	**ACSM**	
Other Medications	**Yes**	Count	3	5	8
		Expected Count	5.1	2.9	8.0
		% within Other	37.5%	62.5%	100.0%
		% within Exer. Program	3.0%	8.9%	5.1%
		% of Total	1.9%	3.2%	5.1%
	No	Count	98	51	149
		Expected Count	95.9	53.1	149.0
		% within Other	65.8%	34.2%	100.0%
		% within Exer. Program	97.0%	91.1%	94.9%
		% of Total	62.4%	32.5%	94.9%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Other	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	2.645	1	0.104

Table 9: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with dehydration while attending their respected exercise program. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Dehydration	**Yes**	Count	2	0	2
		Expected Count	1.3	0.7	2.0
		% within Dehydration	100.0%	0.0%	100.0%
		% within Exer. Program	2.0%	0.0%	1.3%
		% of Total	1.3%	0.0%	1.3%
	No	Count	99	56	155
		Expected Count	99.7	55.3	155.0
		% within Dehydration	63.9%	36.1%	100.0%
		% within Exer. Program	98.0%	100.0%	98.7%
		% of Total	63.1%	35.7%	98.7%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Dehydration	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	1.123	1	0.289

Table 10: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with fatigue while attending their respected exercise program. (pg. 7)

			Exercise Program		**Total**
			CrossFit	**ACSM**	
Fatigue	**Yes**	Count	0	2	2
		Expected Count	1.3	0.7	2.0
		% within Fatigue	0.0%	100.0%	100.0%
		% within Exer. Program	0.0%	3.6%	1.3%
		% of Total	0.0%	1.3%	1.3%
	No	Count	101	54	155
		Expected Count	99.7	55.3	155.0
		% within Fatigue	65.2%	34.8%	100.0%
		% within Exer. Program	100.0%	96.4%	98.7%
		% of Total	64.3%	34.4%	98.7%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Fatigue	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	3.654	1	0.056

Table 11: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with delayed onset muscle soreness (DOMS) while attending their respected exercise program. (pg. 7)

			Exercise Program		**Total**
			CrossFit	**ACSM**	
Delayed Onset Muscles Soreness	**Yes**	Count	3	1	4
		Expected Count	2.6	1.4	4.0
		% within DOMS	75.0%	25.0%	100.0%
		% within Exer. Program	3.0%	1.8%	2.5%
		% of Total	1.9%	0.6%	2.5%
	No	Count	98	55	153
		Expected Count	98.4	54.6	153.0
		% within DOMS	64.1%	35.9%	100.0%
		% within Exer. Program	97.0%	98.2%	97.5%
		% of Total	62.4%	35.0%	97.5%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within DOMS	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	0.204	1	0.652

Table 12: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with overexertion injury while attending their respected exercise program. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Overexertion Injury	**Yes**	Count	4	3	7
		Expected Count	4.5	2.5	7.0
		% within Overexertion Injury	57.1%	42.9%	100.0%
		% within Exer. Program	4.0%	5.4%	4.5%
		% of Total	2.5%	1.9%	4.5%
	No	Count	97	53	150
		Expected Count	96.5	53.5	150.0
		% within Overexertion Injury	64.7%	35.3%	100.0%
		% within Exer. Program	96.0%	94.6%	95.5%
		% of Total	61.8%	33.8%	95.5%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Overexertion Injury	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	0.165	1	0.685

Table 13: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with other medical conditions while attending their respected exercise program. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Other Conditions	**Yes**	Count	3	3	6
		Expected Count	3.9	2.1	6.0
		% within Other Conditions	50.0%	50.0%	100.0%
		% within Exer. Program	3.0%	5.4%	3.8%
		% of Total	1.9%	1.9%	3.8%
	No	Count	98	53	151
		Expected Count	97.1	53.9	151.0
		% within Other Conditions	64.9%	35.1%	100.0%
		% within Exer. Program	97.0%	94.6%	96.2%
		% of Total	62.4%	33.8%	96.2%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Other Conditions	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	0.558	1	0.455

Table 14: Chi-square analysis via crosstabulation as to whether participants had experienced excessive fatigue within 48-hours of completing a workout. (pg. 7)

			Exercise Program		Total
			CrossFit	ACSM	
Excessive Fatigue	**Yes**	Count	42	8	50
		Expected Count	32.2	17.8	50.0
		% within Excessive Fatigue	84.0%	16.0%	100.0%
		% within Exer. Program	41.6%	14.3%	31.8%
		% of Total	26.8%	5.1%	31.8%
	No	Count	59	48	107
		Expected Count	68.8	38.2	107.0
		% within Excessive Fatigue	55.1%	44.9%	100.0%
		% within Exer. Program	58.4%	85.7%	68.2%
		% of Total	37.6%	30.6%	68.2%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Excessive Fatigue	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	12.369	1	<0.001

Table 15: Chi-square analysis via crosstabulation as to whether participants had experienced muscle soreness within 48-hours of completing a workout. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Muscle Soreness	**Yes**	Count	96	48	144
		Expected Count	92.6	51.4	144.0
		% within Muscle Soreness	66.7%	33.3%	100.0%
		% within Exer. Program	95.0%	85.7%	91.7%
		% of Total	61.1%	30.6%	91.7%
	No	Count	5	8	13
		Expected Count	8.4	4.6	13.0
		% within Muscle Soreness	38.5%	61.5%	100.0%
		% within Exer. Program	5.0%	14.3%	8.3%
		% of Total	3.2%	5.1%	8.3%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Muscle Soreness	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	4.134	1	0.042

Table 16: Chi-square analysis via crosstabulation as to whether participants had experienced muscle swelling within 48-hours of completing a workout. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Muscle Swelling	**Yes**	Count	19	4	23
		Expected Count	14.8	8.2	23.0
		% within Muscle Swelling	82.6%	17.4%	100.0%
		% within Exer. Program	18.8%	7.1%	14.6%
		% of Total	12.1%	2.5%	14.6%
	No	Count	82	52	134
		Expected Count	86.2	47.8	134.0
		% within Muscle Swelling	61.2%	38.8%	100.0%
		% within Exer. Program	81.2%	92.9%	85.4%
		% of Total	52.2%	33.1%	85.4%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Muscle Swelling	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	3.923	1	0.048

Table 17: Chi-square analysis via crosstabulation as to whether participants had experienced shortness of breath (SOB) within 48-hours of completing a workout. (pg. 7)

			Exercise Program		**Total**
			CrossFit	**ACSM**	
Shortness of Breath	**Yes**	Count	13	1	14
		Expected Count	9.0	5.0	14.0
		% within SOB	92.9%	7.1%	100.0%
		% within Exer. Program	12.9%	1.8%	8.9%
		% of Total	8.3%	0.6%	8.9%
	No	Count	88	55	143
		Expected Count	92.0	51.0	143.0
		% within SOB	61.5%	38.5%	100.0%
		% within Exer. Program	87.1%	98.2%	91.1%
		% of Total	56.1%	35.0%	91.1%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within SOB	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	5.451	1	0.020

Table 18: Chi-square analysis via crosstabulation as to whether participants had experienced muscle weakness within 48-hours of completing a workout. (pg. 7)

			Exercise Program		Total
			CrossFit	ACSM	
Muscle Weakness	**Yes**	Count	31	12	43
		Expected Count	27.7	15.3	43.0
		% within Muscle Weakness	72.1%	27.9%	100.0%
		% within Exer. Program	30.7%	21.4%	27.4%
		% of Total	19.7%	7.6%	27.4%
	No	Count	70	44	114
		Expected Count	73.3	40.7	114.0
		% within Muscle Weakness	61.4%	38.6%	100.0%
		% within Exer. Program	69.3%	78.6%	72.6%
		% of Total	44.6%	28.0%	72.6%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Muscle Weakness	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	1.555	1	0.212

Table 19: Chi-square analysis via crosstabulation as to whether participants had experienced sleep disturbances within 48-hours of completing a workout. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Sleep Disturbances	**Yes**	Count	11	4	15
		Expected Count	9.6	5.4	15.0
		% within Sleep Disturbances	73.3%	26.7%	100.0%
		% within Exer. Program	10.9%	7.1%	9.6%
		% of Total	7.0%	2.5%	9.6%
	No	Count	90	52	142
		Expected Count	91.4	50.6	142.0
		% within Sleep Disturbances	63.4%	36.6%	100.0%
		% within Exer. Program	89.1%	92.9%	90.4%
		% of Total	57.3%	33.1%	90.4%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Sleep Disturbances	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	0.586	1	0.444

Table 20: Chi-square analysis via crosstabulation as to whether participants had experienced muscle pain to light tight (MPLT) within 48-hours of completing a workout. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Muscle Pain to Light Touch	**Yes**	Count	31	4	35
		Expected Count	22.5	12.5	35.0
		% within MPLT	88.6%	11.4%	100.0%
		% within Exer. Program	30.7%	7.1%	22.3%
		% of Total	19.7%	2.5%	22.3%
	No	Count	70	52	122
		Expected Count	78.5	43.5	122.0
		% within MPLT	57.4%	42.6%	100.0%
		% within Exer. Program	69.3%	92.9%	77.7%
		% of Total	44.6%	33.1%	77.7%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within MPLT	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-square	11.534	1	0.001

Table 21: Chi-square analysis via crosstabulation as to whether participants had experienced limited movement in muscles used during the workout (LMMW) within 48-hours of completing a workout. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Limited Movement in Muscles used during the Workout	**Yes**	Count	37	9	46
		Expected Count	29.6	16.4	46.0
		% within LMMW	80.4%	19.6%	100.0%
		% within Exer. Program	36.6%	16.1%	29.3%
		% of Total	23.6%	5.7%	29.3%
	No	Count	64	47	111
		Expected Count	71.4	39.6	111.0
		% within LMMW	57.7%	42.3%	100.0%
		% within Exer. Program	63.4%	83.9%	70.7%
		% of Total	40.8%	29.9%	70.7%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within LMMW	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	7.353	1	0.007

Table 22: Chi-square analysis via crosstabulation as to whether participants had experienced chest pain within 48-hours of completing a workout. (pg. 7)

			Exercise Program		**Total**
			CrossFit	**ACSM**	
Chest Pain	**Yes**	Count	5	2	7
		Expected Count	4.5	2.5	7.0
		% within Chest Pain	71.4%	28.6%	100.0%
		% within Exer. Program	5.0%	3.6%	4.5%
		% of Total	3.2%	1.3%	4.5%
	No	Count	96	54	150
		Expected Count	96.5	53.5	150.0
		% within Chest Pain	64.0%	36.0%	100.0%
		% within Exer. Program	95.0%	96.4%	95.5%
		% of Total	61.1%	34.4%	95.5%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Chest Pain	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	0.161	1	0.688

Table 23: Chi-square analysis via crosstabulation as to whether participants had experienced cola-/tea-/brown-colored urine (CTBU) within 48-hours of completing a workout. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Cola-/Tea-/Brown-colored Urine	**Yes**	Count	2	0	2
		Expected Count	1.3	0.7	2.0
		% within CTBU	100.0%	0.0%	100.0%
		% within Exer. Program	2.0%	0.0%	1.3%
		% of Total	1.3%	0.0%	1.3%
	No	Count	99	56	155
		Expected Count	99.7	55.3	155.0
		% within CTBU	63.9%	36.1%	100.0%
		% within Exer. Program	98.0%	100.0%	98.7%
		% of Total	63.1%	35.7%	98.7%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within CTBU	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	1.123	1	0.289

Table 24: Chi-square analysis via crosstabulation as to whether participants had experienced other symptoms within 48-hours of completing a workout. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Other Symptoms	**Yes**	Count	0	1	1
		Expected Count	0.6	0.4	1.0
		% within Other Symptoms	0.0%	100.0%	100.0%
		% within Exer. Program	0.0%	1.8%	0.6%
		% of Total	0.0%	0.6%	0.6%
	No	Count	101	55	156
		Expected Count	100.4	55.6	156.0
		% within Other Symptoms	64.7%	35.3%	100.0%
		% within Exer. Program	100.0%	98.2%	99.4%
		% of Total	64.3%	35.0%	99.4%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Other Symptoms	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-square	1.815	1	0.178

Table 25: Chi-square analysis via crosstabulation as to whether participants sought medical attention for symptoms they had experienced within 48-hours of completing a workout. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Medical Attention Required	**Yes**	Count	8	5	13
		Expected Count	8.4	4.5	13.0
		% within Medical Attention	61.5%	38.5%	100.0%
		% within Exer. Program	7.9%	8.9%	8.3%
		% of Total	5.1%	3.2%	8.3%
	No	Count	93	51	144
		Expected Count	92.6	51.4	144.0
		% within Medical Attention	64.6%	35.4%	100.0%
		% within Exer. Program	92.1%	91.1%	91.7%
		% of Total	59.2%	32.5%	91.7%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Medical Attention	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	0.048	1	0.826

Table 26: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with myoglobinuria (MG), an indicator of ER. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Myoglobinuria	**Yes**	Count	1	1	2
		Expected Count	1.3	0.7	2.0
		% within MG	50.0%	50.0%	100.0%
		% within Exer. Program	1.0%	1.8%	1.3%
		% of Total	0.6%	0.6%	1.3%
	No	Count	100	55	155
		Expected Count	99.7	55.3	155.0
		% within MG	64.5%	35.5%	100.0%
		% within Exer. Program	99.0%	98.2%	98.7%
		% of Total	63.7%	35.0%	98.7%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within MG	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	0.181	1	0.670

Table 27: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with high serum creatine kinase (CK) levels, an indicator of ER. (pg. 7)

			Exercise Program		**Total**
			CrossFit	**ACSM**	
High Serum Creatine Kinase Levels	**Yes**	Count	2	1	3
		Expected Count	1.9	1.1	3.0
		% within CK Levels	66.7%	33.3%	100.0%
		% within Exer. Program	2.0%	1.8%	1.9%
		% of Total	1.3%	0.6%	1.9%
	No	Count	99	55	154
		Expected Count	99.1	54.9	154.0
		% within CK Levels	64.3%	35.7%	100.0%
		% within Exer. Program	98.0%	98.2%	98.1%
		% of Total	63.1%	35.0%	98.1%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within CK Levels	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test			
	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	0.007	1	0.932

Table 28: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with arrhythmia, a complication of ER. (pg. 7)

			Exercise Program		**Total**
			CrossFit	**ACSM**	
Arrhythmia	**Yes**	Count	2	3	5
		Expected Count	3.2	1.8	5.0
		% within Arrhythmia	40.0%	60.0%	100.0%
		% within Exer. Program	2.0%	5.4%	3.2%
		% of Total	1.3%	1.9%	3.2%
	No	Count	99	53	152
		Expected Count	97.8	54.2	152.0
		% within Arrhythmia	65.1%	34.9%	100.0%
		% within Exer. Program	98.0%	94.5%	96.8%
		% of Total	63.1%	33.8%	96.8%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Arrhythmia	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	1.332	1	0.248

Table 29: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with hyperkalemia, a complication of ER. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Hyperkalemia	**Yes**	Count	1	0	1
		Expected Count	0.6	0.4	1.0
		% within Hyperkalemia	100.0%	0.0%	100.0%
		% within Exer. Program	1.0%	0.0%	0.6%
		% of Total	0.6%	0.0%	0.6%
	No	Count	100	56	156
		Expected Count	100.4	55.6	156.0
		% within Hyperkalemia	64.1%	35.9%	100.0%
		% within Exer. Program	99.0%	100.0%	99.4%
		% of Total	63.7%	35.7%	99.4%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Hyperkalemia	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-square	0.558	1	0.455

Table 30: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with muscle compartment syndrome (MSC), a complication of ER. (pg. 7)

			Exercise Program		**Total**
			CrossFit	**ACSM**	
Muscle Compartment Syndrome	**Yes**	Count	0	1	1
		Expected Count	0.6	0.4	1.0
		% within MCS	0.0%	100.0%	100.0%
		% within Exer. Program	0.0%	1.8%	0.6%
		% of Total	0.0%	0.6%	0.6%
	No	Count	101	55	156
		Expected Count	100.4	55.6	156.0
		% within MCS	64.7%	35.3%	100.0%
		% within Exer. Program	100.0%	98.2%	99.4%
		% of Total	64.3%	35.0%	99.4%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within MCS	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	1.815	1	0.178

Table 31: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with any other medical conditions. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Other	**Yes**	Count	0	1	1
		Expected Count	0.6	0.4	1.0
		% within Other	0.0%	100.0%	100.0%
		% within Exer. Program	0.0%	1.8%	0.6%
		% of Total	0.0%	0.6%	0.6%
	No	Count	101	55	156
		Expected Count	100.4	55.6	156.0
		% within Other	64.7%	35.3%	100.0%
		% within Exer. Program	100.0%	98.2%	99.4%
		% of Total	64.3%	35.0%	99.4%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Other	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-square	1.815	1	0.178

Table 32: Chi-square analysis via crosstabulation as to whether participants had to stay overnight at a hospital due to medical conditions related to ER. (pg. 7)

			Exercise Program		Total
			CrossFit	**ACSM**	
Stay Overnight at a Hospital	**Yes**	Count	1	2	3
		Expected Count	1.9	1.1	3.0
		% within Stay Overnight	33.3%	66.7%	100.0%
		% within Exer. Program	1.0%	3.6%	1.9%
		% of Total	0.6%	1.3%	1.9%
	No	Count	100	54	154
		Expected Count	99.1	54.9	154.0
		% within Stay Overnight	64.9%	35.1%	100.0%
		% within Exer. Program	99.0%	96.4%	98.1%
		% of Total	63.7%	34.4%	98.1%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Stay Overnight	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	1.281	1	0.258

Table 33: Chi-square analysis via crosstabulation as to whether participants had been diagnosed with ER. (pg. 7)

			Exercise Program		**Total**
			CrossFit	**ACSM**	
Diagnosed with ER	**Yes**	Count	1	0	1
		Expected Count	0.6	0.4	1.0
		% within Diagnosed with ER	100.0%	0.0%	100.0%
		% within Exer. Program	1.0%	0.0%	0.6%
		% of Total	0.6%	0.0%	0.6%
	No	Count	100	56	156
		Expected Count	100.4	55.6	156.0
		% within Diagnosed with ER	64.1%	35.9%	100.0%
		% within Exer. Program	99.0%	100.0%	99.4%
		% of Total	63.7%	35.7%	99.4%
Total		Count	101	56	157
		Expected Count	101.0	56.0	157.0
		% within Diagnosed with ER	64.3%	35.7%	100.0%
		% within Exer. Program	100.0%	100.0%	100.0%
		% of Total	64.3%	35.7%	100.0%

Chi-square Test

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-square	0.558	1	0.455

Table 34: The frequency of workouts of the day (WODs) as reported by the CrossFit® group. (pg. 10)

WODs	Frequency	Percent (%)	WODs	Frequency	Percent (%)
JT	2	0.9	**Hotshots**	1	0.5
Nancy	3	1.4	**Griff**	1	0.5
Fight Gone Bad	10	4.7	**Manion**	1	0.5
Fran	47	22.3	**Barbara**	3	1.4
Kelly	2	0.9	**King Kong**	4	1.9
Karen	6	2.8	**Mondays**	1	0.5
DT	5	2.4	**The Sevens**	5	2.4
Elizabeth	7	3.3	**Glen**	1	0.5
Helen	9	4.3	**Deck of Cards**	1	0.5
Cindy	7	3.3	**Blake**	1	0.5
2008	1	0.5	**Barbell Hell**	1	0.5
Kalsu	6	2.8	**Roy**	2	0.9
Tears of the Spider Monkey	1	0.5	**Annie**	5	2.4
Murph	27	12.8	**Mr. Joshua**	1	0.5
Chelsea	1	0.5	**13.1**	3	1.4
Linda	1	0.5	**Ship**	1	0.5
Diane	8	3.8	**Nutts**	1	0.5
Angie	3	1.4	**Jackie**	2	0.9
Lumber Jack 20	2	0.9	**Arnie**	1	0.5
FYF	1	0.5	**Bull**	1	0.5
Grace	6	2.8	**Tommy V**	1	0.5
Filthy 50	9	4.3	**Gallant**	1	0.5
Eva	8	3.8			
			TOTAL	211	100.0

Table 35: The Borg Category Ratings Scale (Ratings of Perceived Exertion Scale) as depicted by Baechle and Earle (7). (pg. 13)

Category-ratio Scale	
0	Noting at all
0.3	
0.5	Extremely weak
1	Very weak
1.5	
2	Weak
2.5	
3	Moderate
4	
5	Strong
6	
7	Very Strong
8	
9	
10	Extremely strong
11	
*	Absolute maximum

Table 36: An example 16 day cycle from the CrossFit® program (19). (pg. 53)

Sixteen-day Cycle
1. Five rounds for time of: Deadlift 185 pounds 15 reps/10 handstand push-ups 2. Run 5K for time 3. How many rounds can you complete in 20 minutes of: 24" Box Jump X 25 reps/5 Muscle-ups? 4. Off 5. How many rounds can you complete in 15 minutes of: Hang squat clean 135 pounds 12 reps/15 Ring dips? 6. 5 sets of 50 Sit-ups on GHD 7. Five rounds for time of: 35 pound Dumbbell thrusters X 15 reps (front squat/push-press)/12 pull-ups 8. Off 9. Five rounds for time of: 60 pound two hand dumbbell swing X 21 reps/Glute-ham developer medicine ball throw sit-up with 12 pound ball X 15 10. One set of max rep pull-ups every 12 minutes or six sets. 11. How many rounds can you complete in 20 minutes of: Run 400 meters/Deadlift 225 pounds X 7 reps? 12. Off 13. Seven rounds for time of: Front squat bodyweight 10 reps/30 feet of rope climb 14. Snatch nine sets 3-3-2-2-2-1-1-1-1 15. How many rounds can you complete in 20 minutes of: Bench press 135 pounds 10 reps/12 "L" Pull-ups? 16. Off

Table 37: Descriptive data for each participant of the 2013 CrossFit® Games and the strength based traditional fitness benchmarks (4). (pg. 55)

Competitors' Finished Rank	Age (years)	Height (cm)	Weight (kg)	Clean and Jerk (kg)	Snatch (kg)	Deadlift (kg)	Back Squat (kg)	Maximum Number of Pull-ups
1	26	175.26	88.45	167.83	136.08	247.21	201.85	75
2	28	175.26	95.25	151.95	120.20	249.48	204.12	50
3	23	180.34	86.18	145.15	129.27	244.94	204.12	76
4	25	175.26	86.18	-	-	-	-	-
5	22	187.96	95.25	147.42	127.01	229.06	192.78	65
6	24	177.80	89.81	151.95	120.20	226.80	181.44	63
7	30	165.10	74.84	-	-	-	-	-
8	29	170.18	81.65	138.35	120.02	244.94	183.71	-
9	35	177.80	92.99	142.88	133.36	229.06	206.39	60
10	24	185.42	97.52	-	-	-	-	-
11	31	185.42	102.06	150.00	130.00	220.00	200.00	45
12	23	177.80	86.18	142.88	111.13	226.80	183.71	50
13	25	180.34	95.25	147.42	120.20	233.60	210.92	-
14	28	180.34	88.45	145.15	117.93	242.67	188.24	53
15	26	174.00	85.00	130.00	100.00	200.00	180.00	30
16	26	170.18	81.65	138.35	115.67	222.26	210.92	56
17	27	182.88	94.35	145.15	120.20	233.60	210.92	60
18	22	-	86.18	140.61	113.40	233.60	195.05	-
19	24	170.18	83.91	151.05	125.65	-	222.26	-
20	31	172.72	83.91	147.42	111.13	219.99	230.43	52
21	35	177.80	95.25	154.68	124.74	247.21	197.31	50
22	26	172.72	86.18	-	115.67	247.21	226.80	-
23	26	185.42	92.99	154.22	129.27	-	-	-
24	29	177.80	81.65	129.27	108.86	215.46	174.63	50
25	26	174.00	85.00	-	-	-	-	-
26	24	-	87.09	129.27	110.22	213.19	179.17	62
27	27	195.58	99.79	-	-	-	-	-
28	25	172.72	81.65	156.49	127.01	227.70	204.12	62
29	28	175.26	89.81	156.49	124.74	229.06	201.85	71
30	29	178.00	89.00	-	-	-	-	-

Table 38: The running based fitness benchmarks for each participant of the 2013 CrossFit®

Games (4). (pg. 55)

Competitors' Finished Rank	Sprint 400m (s)	Run 5k (s)
1	-	-
2	63	1400
3	58	1220
4	-	-
5	55	1097
6	55	-
7	-	-
8	47	1140
9	70	-
10	-	-
11	60	1200
12	-	1190
13	-	-
14	60	1140
15	67	1340
16	57	1140
17	60	1272
18	-	1083
19	-	-
20	51	1151
21	60	1318
22	56	1285
23	-	-
24	55	1115
25	-	-
26	-	1215
27	-	-
28	-	-
29	57	-
30	-	-

Table 39: Bivariate correlation factoring in the groupings of T10, M10 and B10 for the fitness benchmarks. (pg. 56)

Correlations

		CleanJerk	Snatch	Deadlift	BackSquat	MaxPullups	Groupof10	Sprint400m	Run5k
CleanJerk	Pearson Correlation	1	.753**	.590**	.467*	.488*	-.119	-.038	.241
	Sig. (2-tailed)		.000	.005	.028	.040	.589	.892	.387
	N	23	23	21	22	18	23	15	15
Snatch	Pearson Correlation	.753**	1	.547**	.311	.651**	-.292	.124	-.028
	Sig. (2-tailed)	.000		.008	.149	.003	.166	.647	.919
	N	23	24	22	23	18	24	16	16
Deadlift	Pearson Correlation	.590**	.547**	1	.325	.498*	-.282	-.174	.178
	Sig. (2-tailed)	.005	.008		.140	.036	.204	.518	.510
	N	21	22	22	22	18	22	16	16
BackSquat	Pearson Correlation	.467*	.311	.325	1	.240	.035	-.026	.173
	Sig. (2-tailed)	.028	.149	.140		.337	.874	.923	.523
	N	22	23	22	23	18	23	16	16
MaxPullups	Pearson Correlation	.488*	.651**	.498*	.240	1	-.239	-.350	-.353
	Sig. (2-tailed)	.040	.003	.036	.337		.339	.220	.237
	N	18	18	18	18	18	18	14	13
Groupof10	Pearson Correlation	-.119	-.292	-.282	.035	-.239	1	-.054	.074
	Sig. (2-tailed)	.589	.166	.204	.874	.339		.844	.784
	N	23	24	22	23	18	30	16	16
Sprint400m	Pearson Correlation	-.038	.124	-.174	-.026	-.350	-.054	1	.681*
	Sig. (2-tailed)	.892	.647	.518	.923	.220	.844		.010
	N	15	16	16	16	14	16	16	13
Run5k	Pearson Correlation	.241	-.028	.178	.173	-.353	.074	.681*	1
	Sig. (2-tailed)	.387	.919	.510	.523	.237	.784	.010	
	N	15	16	16	16	13	16	13	16

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 40: Partial correlation when controlling for the groupings of T10, M10 and B10 for the fitness benchmarks. (pg. 56)

Correlations

Control Variables			CleanJerk	Snatch	Deadlift	BackSquat	MaxPullups	Sprint400m	Run5k
Groupof10	CleanJerk	Correlation	1.000	.734	.715	.486	.233	-.120	.220
		Significance (2-tailed)	.	.016	.020	.154	.517	.742	.541
		df	0	8	8	8	8	8	8
	Snatch	Correlation	.734	1.000	.631	.164	.577	-.203	-.117
		Significance (2-tailed)	.016	.	.051	.651	.081	.574	.747
		df	8	0	8	8	8	8	8
	Deadlift	Correlation	.715	.631	1.000	.169	.525	-.019	.230
		Significance (2-tailed)	.020	.051	.	.641	.119	.959	.523
		df	8	8	0	8	8	8	8
	BackSquat	Correlation	.486	.164	.169	1.000	.254	-.469	-.017
		Significance (2-tailed)	.154	.651	.641	.	.478	.171	.964
		df	8	8	8	0	8	8	8
	MaxPullups	Correlation	.233	.577	.525	.254	1.000	-.620	-.470
		Significance (2-tailed)	.517	.081	.119	.478	.	.056	.170
		df	8	8	8	8	0	8	8
	Sprint400m	Correlation	-.120	-.203	-.019	-.469	-.620	1.000	.766
		Significance (2-tailed)	.742	.574	.959	.171	.056	.	.010
		df	8	8	8	8	8	0	8
	Run5k	Correlation	.220	-.117	.230	-.017	-.470	.766	1.000
		Significance (2-tailed)	.541	.747	.523	.964	.170	.010	.
		df	8	8	8	8	8	8	0

Table 41: One-way ANOVA for maximum number of pull-ups (n = 18). (pg. 57)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	788.563	2	394.282	4.315	0.033
Within Groups	1370.548	15	91.370		
Total	2159.111	17			

Table 42: One-way ANOVA for the snatch (n = 24). (pg. 57)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	418.545	2	209.273	3.324	0.056
Within Groups	1322.159	21	62.960		
Total	1740.705	23			

Table 43: One-way ANOVA for the deadlift (n = 22). (pg. 57)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	670.400	2	335.200	2.196	0.139
Within Groups	2900.121	19	152.638		
Total	3570.521	21			

Table 44: One-way ANOVA for the back squat (n = 23). (pg. 58)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	238.431	2	119.215	0.484	0.623
Within Groups	4928.805	20	246.440		
Total	5167.236	22			

Table 45: One-way ANOVA for the 400 m sprint (n = 16). (pg. 58)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11.604	2	5.802	0.165	0.850
Within Groups	456.833	13	35.141		
Total	468.438	15			

Table 46: One-way ANOVA for the 5 k run (n = 16). (pg. 58)

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	5414.250	2	2707.125	0.281	0.760
Within Groups	125265.500	13	9635.808		
Total	130679.750	15			

Table 47: Independent T-Test for comparing T10 and M10 in the clean & jerk. (pg. 58)

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Clean & Jerk Equal variances assumed	0.758	0.398	1.463	15	0.164	5.55843	3.79871	-2.53833	13.65519
Equal variances not assumed			1.358	9.617	0.205	5.55843	4.09277	-3.61024	14.72710

Table 48: Independent T-Test for comparing T10 and B10 in the clean & jerk. (pg. 58)

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Clean & Jerk Equal variances assumed	2.607	0.135	0.410	11	0.690	2.62476	6.40686	-11.47663	16.72616
Equal variances not assumed			0.398	8.782	0.700	2.62476	6.59470	-12.35010	17.59962

Table 49: Independent T-Test for comparing M10 and B10 in the clean & jerk. (pg. 58)

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Clean & Jerk Equal variances assumed	10.650	0.006	-0.596	14	0.561	-2.93367	4.92137	-13.48895	7.62161
Equal variances not assumed			-0.499	6.301	0.635	-2.93367	5.87895	-17.15424	11.28690

Table 50: Performance rankings of highest, middle and lowest for T10, M10 and B10 on the fitness benchmarks based on the means for each benchmark for each group. (pg. 59)

Fitness Benchmark	**Rating of Performance on Fitness Benchmarks**			**Energy System**
	Highest	**Middle**	**Lowest**	
Clean & Jerk	Top 10	Bottom 10	Middle 10	Anaerobic
Snatch	Top 10	Bottom 10	Middle 10	Anaerobic
Deadlift	Top 10	Bottom 10	Middle 10	Anaerobic
Back Squat	Middle 10	Bottom 10	Top 10	Anaerobic
Max Pull-ups	Top 10	Bottom 10	Middle 10	Aerobic
400 m Sprint	Bottom 10	Top 10	Middle 10	Anaerobic
5 k Run	Middle 10	Top 10	Bottom 10	Aerobic

Table 51: The Intraclass Correlation for the questions concerning average RPE for the workouts, number of hard days performed in a week and number of weeks of participation that has occurred in the self-selected program. (pg. 120)

	Number of Hard Days in a Week	Average RPE for the Workouts	Number of Weeks Completed in the Exercise Program
Intraclass Correlation	0.971	0.902	0.801

Table 52: Strength of agreements based on Cohen's Kappa statistic from Landis and Koch (31). (pg. 120)

Strength of Agreement	**Cohen's Kappa Statistic (κ)**
Poor	<0.00
Slight	0.00 – 0.20
Fair	0.21 – 0.40
Moderate	0.41 – 0.60
Substantial	0.61 – 0.80
Almost Perfect	0.81 – 1.00

Table 53: Reliability analysis via Cohen's kappa and Landis and Koch (31) depicting poor, slight, fair, moderate (Mod.), substantial (Substan.) and almost perfect agreements for the yes/no questions of the questionnaire. (pg. 120)

		TRIAL 2													
QUESTION #		**Q7**		**Q12**		**Q13A1**		**Q13A2**		**Q13A3**		**Q13A4**		**Q13A5**	
		Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
TRIAL 1	**Yes**	9	0	13	0	5	0	0	0	0	0	0	0	0	1
	No	1	8	0	5	0	13	0	18	0	18	0	18	0	17
COHENS' KAPPA (κ)		0.88		1.00		1.00		-		-		-		0.00	
AGREEMENT		Almost Perfect		Almost Perfect		Almost Perfect		Almost Perfect		Almost Perfect		Almost Perfect		Slight	
QUESTION #		**Q14A1**		**Q14A2**		**Q14A3**		**Q14A4**		**Q14A5**		**Q14A6**		**Q14A7**	
		Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
TRIAL 1		0	0	0	0	0	0	0	0	0	0	0	0	0	1
		0	18	0	18	0	18	0	18	0	18	0	18	0	17
COHENS' KAPPA (κ)		-		-		-		-		-		-		0.00	
AGREEMENT		Almost Perfect		Almost Perfect		Almost Perfect		Almost Perfect		Almost Perfect		Almost Perfect		Slight	
QUESTION #		**Q14A8**		**Q15A1**		**Q15A2**		**Q15A3**		**Q15A4**		**Q15A5**		**Q15A6**	
		Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
TRIAL 1		0	0	1	3	9	3	1	1	1	0	3	0	1	1
		0	18	2	12	1	5	0	16	0	17	1	14	0	16
COHENS' KAPPA (κ)		-		0.10		0.53		0.61		1.00		0.81		0.61	
AGREEMENT		Almost Perfect		Slight		Mod.		Substan.		Almost Perfect		Almost Perfect		Substan.	
QUESTION #		**Q15A7**		**Q15A8**		**Q15A9**		**Q15A10**		**Q15A11**		**Q16**		**Q17A1**	
		Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
TRIAL 1	**Yes**	0	3	1	1	0	1	1	0	0	0	1	1	0	0
	No	0	15	1	15	0	17	0	17	0	18	1	15	0	18
COHENS' KAPPA (κ)		0.00		0.45		0.00		1.00		-		0.45		-	
AGREEMENT		Slight		Mod.		Slight		Almost Perfect		Almost Perfect		Mod.		Almost Perfect	

QUESTION #		**Q17A2**		**Q17A3**		**Q17A4**		**Q17A5**		**Q17A6**		**Q17A7**		**Q17A8**	
		Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
TRIAL 1	**Yes**	0	0	0	1	0	0	0	0	0	0	0	0	0	2
	No	0	18	0	17	0	18	0	18	0	18	0	18	0	16
COHENS' KAPPA (κ)		-		0.00		-		-		-		-		0.00	
AGREEMENT		Almost Perfect		Slight		Almost Perfect		Almost Perfect		Almost Perfect		Almost Perfect		Slight	

QUESTION #		**Q18**		**Q19**	
		Yes	**No**	**Yes**	**No**
TRIAL 1	**Yes**	0	0	0	0
	No	0	18	0	18
COHENS' KAPPA (κ)		-		-	
AGREEMENT		Almost Perfect		Almost Perfect	

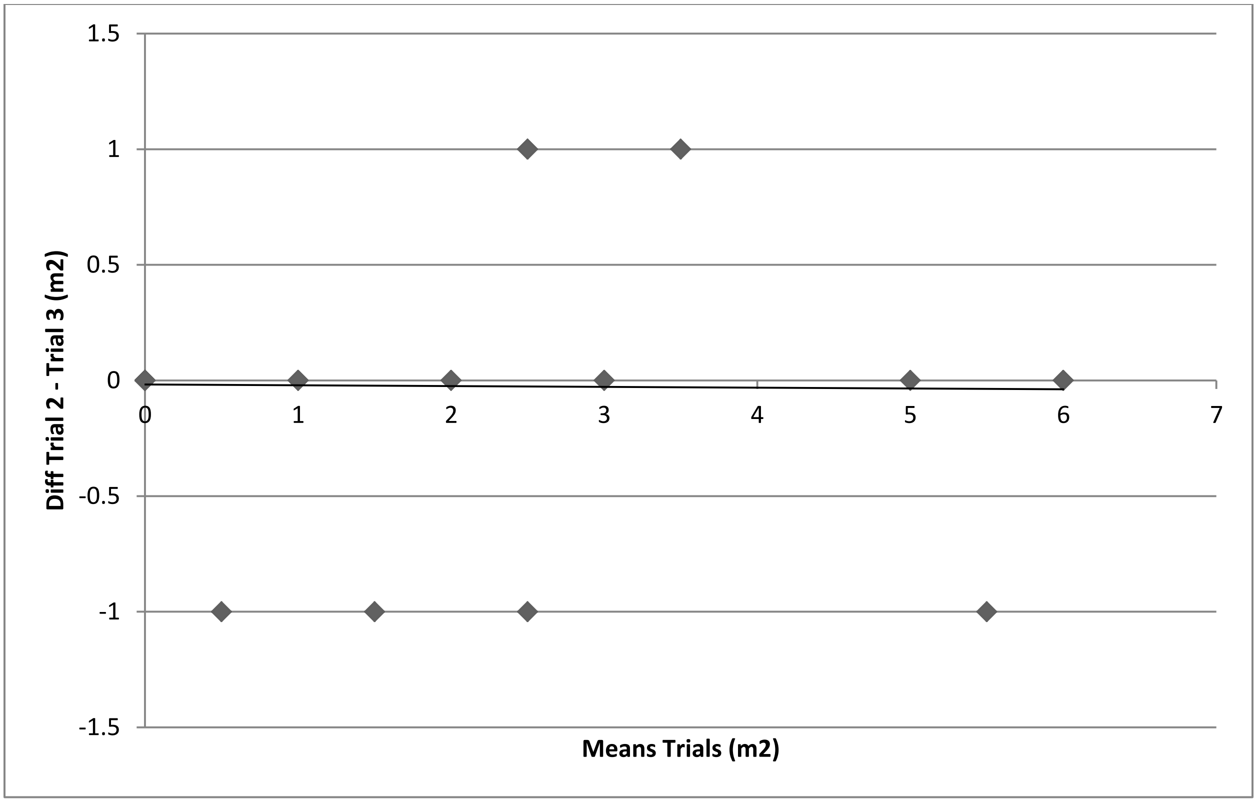

Figure 1: Bland-Altman plot for the number of hard days performed in a week. (pg. 120)

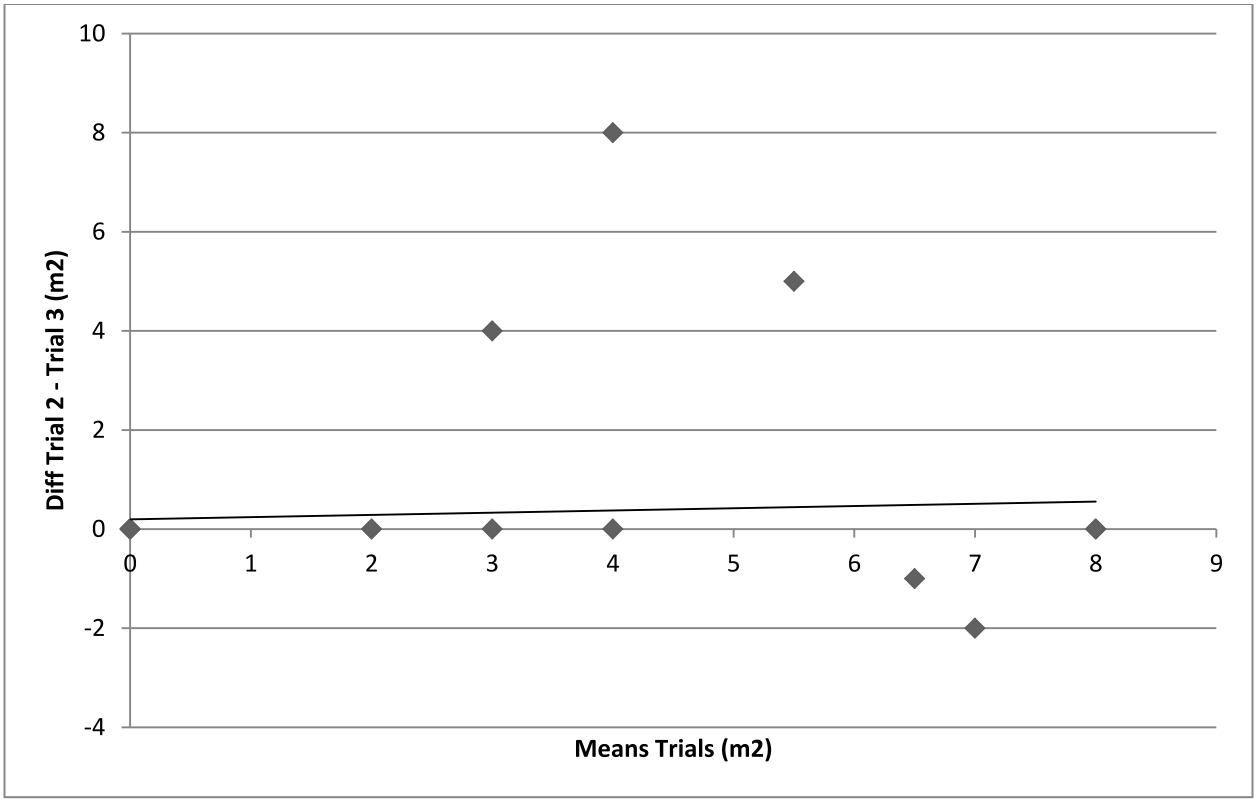

Figure 2: Bland-Altman plot for the number of weeks of participation that has occurred in the self-selected program. (pg. 120)

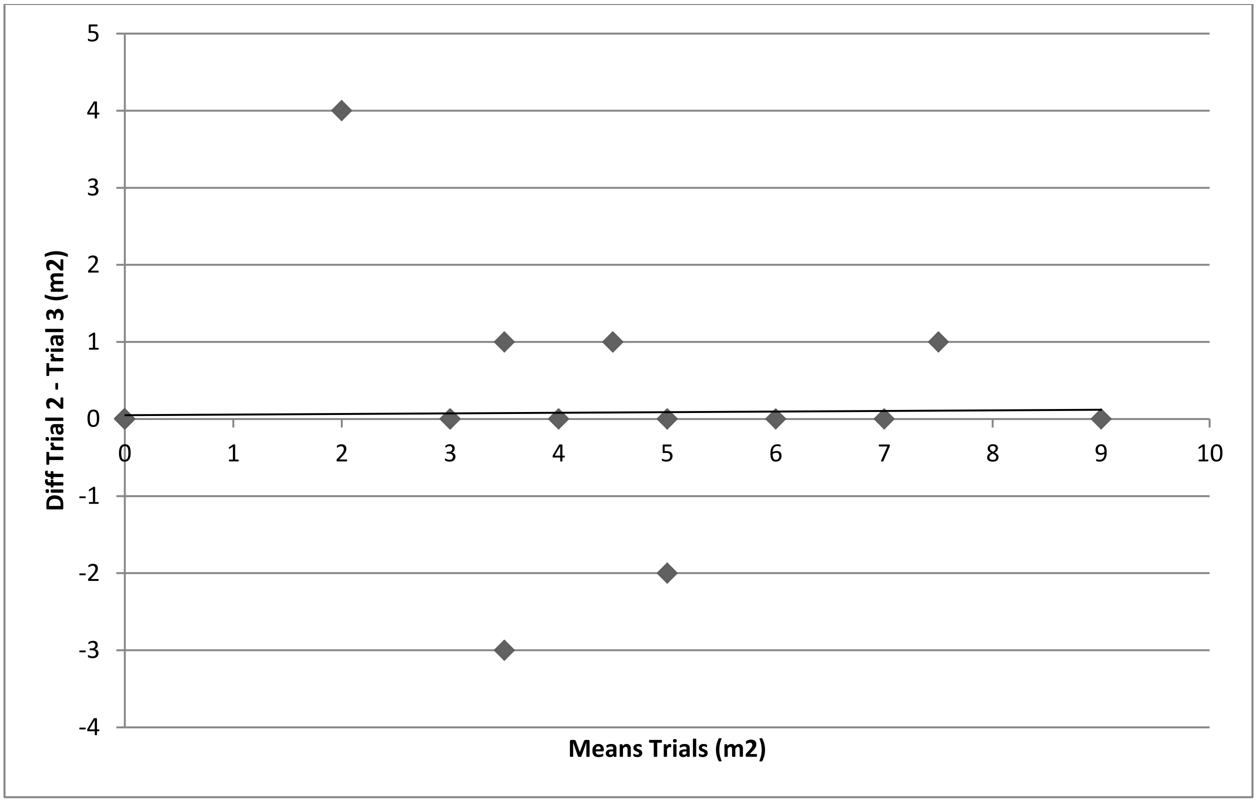

Figure 3: Bland-Altman plot for the average RPE for the workouts. (pg. 120)

APPENDIX C

A QUESTIONNAIRE’S RELIABILITIY IN DETERMINING RISK FACTORS OF EXERTIONAL RHABDOMYOLYSIS IN EXTREME CONDITIONING PROGRAMS

SUBJECTS AND PROCEDURES

Prior to sending out an official questionnaire to CrossFit® and American College of Sports Medicine (ACSM) trained individuals, 62 individuals were contacted to take the Exercise Training Study Questionnaire (Appendix D) to determine its reliability. Eighteen subjects (17 females and one male) of the 62 volunteered to participate in determining the reliability of the Exercise Training Study Questionnaire via the test-retest method. Subjects used were not those consistent with the target exercisers following the CrossFit® or ACSM program. The subjects were asked to complete the questionnaire via email twice with a reminder email sent to retake the questionnaire two days later after having all the risks explained to them and giving informed consent (Appendix G).

STATISTICAL ANALYSIS

The intraclass correlation (ICC) was determine for the questions pertaining to RPE, number of hard days performed in a week and number of weeks of participation that occurred in the self-selected program. In addition, Bland-Altman plots were created for these questions. As the rest of the questions consisted of yes/no items, Cohen’s kappa was used to determine the agreement between the first answer given and the second one. Agreement was determined via techniques of Landis and Koch (31).

RESULTS

Due to normality calculated as less than 2.58 for the questions concerning RPE, number of hard days performed in a week and number of weeks of participation that occurred in the self-selected program, ICC was determined to be an appropriate analysis of the three prior mentioned questions. The ICC (Table 51) for RPE, number of hard days performed in a week, and number of weeks of participation that occurred in the self-selected program were 0.902, 0.971 and 0.801, respectively. The Bland-Altman plots depict this agreement in Figures 1 – 3.

For the yes/no questions, Cohen's kappa was used and agreements were determined by referencing Landis and Koch (31) as illustrated in Table 52. Yes or no questions consisted of questions five & 10 – 19. In summary, questions regarding RPE, number of hard days performed in a week, and number of weeks of participation that occurred in the self-selected program, had strong ICC reliability values. As for the yes/no questions, there were zero agreements of poor, seven agreements of slight, zero agreements of fair, three agreements of moderate, two agreements of substantial, and 25 agreements of almost perfect. The specific data collected on the reliability analysis on the strength of agreements can be found in Table 53.

DISCUSSION AND CONCLUSION

As the ICC for RPE, number of hard days performed in a week and number of weeks of participation that occurred in the self-selected program was 0.902, 0.971 and 0.801 (Table 51), respectively; this indicated very good reliability for these questions.

Landis and Koch (31) found that the kappa statistic (κ) was related to the strength of agreement between the two variables, and therefore could yield an general idea of reliability for the yes/no questions. Ideally the "almost perfect" agreement was sought after for the yes/no questions; however, some questions did not hold that agreement. The most troubling were those where one to three subjects changed one of their answers on one question from "yes" on the first trial to "no" on the second trial. This would result in $\kappa = 0.00$ and a slight agreement (Table 52) though it would seem reliability to be quite good with just one to three people switching one answer to one question. This may be due to small sample size (18 subjects) or possibly due to where the subject was in the periodization of their chosen exercise program resulting in changing their answer. Question 15 had greatest range in strength of agreement as the subjects answered the yes/no questions. Strength of agreement ranged from slight to almost perfect. This may be due to the nature of the question, which asked: within 48-hours of any workout, have you had any of the symptoms mentioned below? It may be possible for the subject to have worked out between trials resulting in additional symptoms being felt. There was also the possibility of forgetting about previous symptoms due to fatigue from taking the questionnaire, crunched for time, boredom, etc. Overall, the questionnaire had 25 questions with almost perfect agreement, two with substantial agreement, three with moderate agreement, and seven with slight agreement. Six of the seven questions with slight agreement involved the incident previously mentioned. Therefore, it was determined that the questionnaire was reliable.

APPENDIX D

ADDITIONAL INFORMATION

This is a list of the exact count and expected count for the crosstabulation for chi-square analysis as they appear in the paper.

Prior exercise experience:

Exact Count - CrossFit®: yes – 80 no – 21, ACSM: yes – 52 no – 4

Expected Count - CrossFit®: yes – 84.9 no – 16.1, ACSM: yes – 47.1 no – 8.9

Warm-up prior to exercise:

Exact Count - CrossFit®: yes – 98 no – 3, ACSM: yes – 52 no – 4

Expected Count - CrossFit®: yes – 96.5 no – 4.5, ACSM: yes – 53.5 no – 2.5

Medications:

Aspirin:

Exact Count - CrossFit®: yes – 12 no – 89, ACSM: yes – 4 no – 52

Expected Count - CrossFit®: yes – 10.3 no – 90.7, ACSM: yes – 5.7 no – 50.3

Anti-Cholinergic Agents:

Exact Count - CrossFit®: yes – 0 no – 101, ACSM: yes – 1 no – 55

Expected Count - CrossFit®: yes – 0.6 no – 100.4, ACSM: yes – 0.4 no – 55.6

Statins:

Exact Count - CrossFit®: yes – 0 no – 101, ACSM: yes – 2 no – 54

Expected Count - CrossFit®: yes – 1.3 no – 99.7, ACSM: yes – 0.7 no – 55.3

Other medications:

Exact Count - CrossFit®: yes – 3 no – 98, ACSM: yes – 5 no – 51

Expected Count - CrossFit®: yes – 5.1 no – 95.9, ACSM: yes – 2.9 no – 53.1

Diagnosis:

Dehydration:

Exact Count - CrossFit®: yes – 2 no – 99, ACSM: yes – 0 no – 56

Expected Count - CrossFit®: yes – 1.3 no – 99.7, ACSM: yes – 0.7 no – 55.3

Fatigue:

Exact Count - CrossFit®: yes – 0 no – 101, ACSM: yes – 2 no – 54

Expected Count - CrossFit®: yes – 1.3 no – 99.7, ACSM: yes – 0.7 no – 55.3

Delayed Onset Muscle Soreness:

Exact Count - CrossFit®: yes – 3 no – 98, ACSM: yes – 1 no – 55

Expected Count - CrossFit®: yes – 2.6 no – 98.4, ACSM: yes – 1.4 no – 54.6

Overexertion Injury:

Exact Count - CrossFit®: yes – 4 no – 97, ACSM: yes – 3 no – 53

Expected Count - CrossFit®: yes – 4.5 no – 96.5, ACSM: yes – 2.5 no – 53.5

Other diagnosed conditions:

Exact Count - CrossFit®: yes – 3 no – 98, ACSM: yes – 3 no – 53

Expected Count - CrossFit®: yes – 3.9 no – 97.1, ACSM: yes – 2.1 no – 53.9

48-hours post-exercise symptoms:

Excessive fatigue:

Exact Count - CrossFit®: yes – 42 no – 59, ACSM: yes – 8 no – 48

Expected Count - CrossFit®: yes – 32.2 no – 68.8, ACSM: yes – 17.8 no – 38.2

Muscle Soreness:

Exact Count - CrossFit®: yes – 96 no – 5, ACSM: yes – 48 no – 8

Expected Count - CrossFit®: yes – 92.6 no – 8.4, ACSM: yes – 51.4 no – 4.6

Muscle Swelling:

Exact Count - CrossFit®: yes – 19 no – 82, ACSM: yes – 4 no – 52

Expected Count - CrossFit®: yes – 14.8 no – 86.2, ACSM: yes – 8.2 no – 47.8

Shortness of breath:

Exact Count - CrossFit®: yes – 13 no – 88, ACSM: yes – 1 no – 55

Expected Count - CrossFit®: yes – 9.0 no – 92.0, ACSM: yes – 5.0 no – 51.0

Muscle Weakness:

Exact Count - CrossFit®: yes – 31 no – 70, ACSM: yes – 12 no – 44

Expected Count - CrossFit®: yes – 27.7 no – 73.3, ACSM: yes – 15.3 no – 40.7

Sleep Disturbance:

Exact Count - CrossFit®: yes – 11 no – 90, ACSM: yes – 4 no – 52

Expected Count - CrossFit®: yes – 9.6 no – 91.4, ACSM: yes – 5.4 no – 50.6

Muscle pain to light touch:

Exact Count - CrossFit®: yes – 31 no – 70, ACSM: yes – 4 no – 52

Expected Count - CrossFit®: yes – 22.5 no – 78.5, ACSM: yes – 12.5 no – 43.5

Limited movement in the muscles used during the workout:

Exact Count - CrossFit®: yes – 37 no – 64, ACSM: yes – 9 no – 47

Expected Count - CrossFit®: yes – 29.6 no – 71.4, ACSM: yes – 16.4 no – 39.6

Chest pain:

Exact Count - CrossFit®: yes – 5 no – 96, ACSM: yes – 2 no – 54

Expected Count - CrossFit®: yes – 4.5 no – 96.5, ACSM: yes – 2.5 no – 53.5

Cola-/Tea-/Brown-colored urine:

Exact Count - CrossFit®: yes – 2 no – 99, ACSM: yes – 0 no – 56

Expected Count - CrossFit®: yes – 1.3 no – 99.7, ACSM: yes – 0.7 no – 55.3

Other 48-hours post-exercise symptoms:

Exact Count - CrossFit®: yes – 0 no – 101, ACSM: yes – 1 no – 55

Expected Count - CrossFit®: yes – 0.6 no – 100.4, ACSM: yes – 0.4 no – 55.6

Doctor seen:

Exact Count - CrossFit®: yes – 8 no – 93, ACSM: yes – 5 no – 51

Expected Count - CrossFit®: yes – 8.4 no – 92.6, ACSM: yes – 4.6 no – 51.4

ER indicators:

Myoglobinuria:

Exact Count - CrossFit®: yes – 1 no – 100, ACSM: yes – 1 no – 55

Expected Count - CrossFit®: yes – 1.3 no – 99.7, ACSM: yes – 0.7 no – 55.3

High blood creatine kinase levels:

Exact Count - CrossFit®: yes – 2 no – 99, ACSM: yes – 1 no – 55

Expected Count - CrossFit®: yes – 1.9 no – 99.1, ACSM: yes – 1.1 no – 54.9

Arrhythmia:

Exact Count - CrossFit®: yes – 2 no – 99, ACSM: yes – 3 no – 53

Expected Count - CrossFit®: yes – 3.2 no – 97.8, ACSM: yes – 1.8 no – 54.2

Hyperkalemia:

Exact Count - CrossFit®: yes – 1 no – 100, ACSM: yes – 0 no – 56

Expected Count - CrossFit®: yes – 0.6 no – 100.4, ACSM: yes – 0.4 no – 55.6

Muscle compartment syndrome:

Exact Count - CrossFit®: yes – 0 no – 101, ACSM: yes – 1 no – 55

Expected Count - CrossFit®: yes – 0.6 no – 100.4, ACSM: yes – 0.4 no – 55.6

Other ER indicators:

Exact Count - CrossFit®: yes – 0 no – 101, ACSM: yes – 1 no – 55

Expected Count - CrossFit®: yes – 0.6 no – 100.4, ACSM: yes – 0.4 no – 55.6

Overnight hospital stay:

Exact Count - CrossFit®: yes – 1 no – 100, ACSM: yes – 2 no – 54

Expected Count - CrossFit®: yes – 1.9 no – 99.1, ACSM: yes – 1.1 no – 54.9

Diagnosed with ER:

Exact Count - CrossFit®: yes – 1 no – 100, ACSM: yes – 0 no – 56

Expected Count - CrossFit®: yes – 0.6 no – 100.4, ACSM: yes – 0.4 no – 55.6

APPENDIX E

EXERCISE TRAINING STUDY QUESTIONNAIRE

For this study, the purpose will be to determine what sort of risk CrossFit® possesses for the development of exertional rhabdomyolysis. Secondary objectives will be to determine if different affiliates and different workouts of the day yield differing risk levels for development of exertional rhabdomyolysis. Lastly, the intensity of CrossFit® will be determined. These objectives will be determined via the answers of CrossFit® participants about their past experiences thru this questionnaire.

1. **Do you participate in a CrossFit® program or an ACSM guideline based program?**

   ☐ CrossFit® ☐ ACSM

   ☐ Other

2. **In what state do you train in?**

   State: ______________________________

3. **Are you male or female?**

   ☐ Male ☐ Female

4. **How old are you?**

   Age: ________________________________

5. **How tall are you?**

   Height: ______________________________

6. **How much do you weigh?**

   Weight: ______________________________

7. **Before starting your current exercise program, did you exercise for at least 3 days per week for at least 30 minutes per day?**

   ☐ Yes ☐ No

8. **How many weeks have you been working out using your current exercise program?**

   ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
   ☐ 6 ☐ 7 ☐ 8 or more

9. **How would you rate your average perceived exertion during a session? (0 – at rest, 1 – very easy, 3 – moderate, 5 – hard, 7- very hard, 10 – maximal)**

   ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4

   ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10

10. **For CrossFit® participants, rank your top 5 hardest workouts of the day with 1 being the hardest and 5 being the least hard.**

    1.____
    2.____
    3.____
    4.____
    5.____

11. On average how many hard days (at least rated a 5 for perceived exertion) would you say you complete in a week?

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
☐ 6 ☐ 7

12. Do you complete a warm-up prior to starting your workout where you become lightly sweaty, feel loose, warm and have an increased heart rate?

☐ Yes ☐ No

13. Do you use any of these medications regularly while participating in the CrossFit° program? Check all that apply; if none don't check any or check other and please explain.

☐ Aspirin
☐ Phenothiazines
☐ Anti-Cholinergic Agents
☐ Statins
☐ Other - Explain: ______________________________

14. Have you been medically diagnosed as having any of these over the course of you attendance at your current exercise program? Check all that apply; if none don't check any or check other and please explain.

☐ Sickle Cell Trait
☐ Renal Insufficiency
☐ Dehydration
☐ Fatigue
☐ Prior History of Heat Exhaustion
☐ Viral Illness while in a Workout Training Program
☐ Delayed Onset Muscle Soreness
☐ High Body Mass Index
☐ Overexertion Injury
☐ Other - Explain: ______________________________

15. During or within 48 hours of any of your workouts have you experienced any of these? Check all that apply; if none don't check any or check other and please explain.

☐ Excessive Fatigue Muscle Soreness Muscle Swelling
☐ Shortness of Breath
☐ Muscle Weakness
☐ Sleep Disturbance
☐ Muscle Pain to Light Touch
☐ Limited Movement in Muscles used during Workout
☐ Chest Pain
☐ Cola-colored Urine
☐ "Doughy" Feeling Muscles
☐ Other - Explain: ______________________________

16. Have you ever gone to see a doctor due to the symptoms mentioned above since participating in your current exercise program?

☐ Yes ☐ No

17. Has a medical doctor told you that you have any of these? Check all that apply; if none don't check any or check other and please explain.

☐ Positive Urine Dipstick Test
☐ Creatine Kinase Level 5 Times above the Normal
☐ Myoglobinuria
☐ Renal Insufficiency or Failure
☐ Arrhythmia
☐ Hyperkalemia (High Potassium Levels)
☐ Hypocalcemia (Low Calcium Levels)
☐ Compartment Syndrome
☐ Other - Explain: ______________________________

18. Did you have to stay overnight due to the previous conditions? If yes, for many nights?

☐ Yes ☐ No

How many nights:______________________

19. Have you ever been medically diagnosed with exertional rhabdomyolysis?

☐ Yes ☐ No

APPENDIX F

INFORMED CONSENT FORM STUDY TESTING

To whom this may concern,

We are inviting you to participate in a research study. The purpose of the study is to compare exercise training programs based on past experiences of their participants. Questions will cover areas concerning your general exercise training background and your perceived intensity of the training program(s).

We are inviting you to be in this study because you are currently participating in an exercise program at the gym of your choosing. Our hope is that you will help provide further insights into your fitness program for future participants to use as they decide the best program to suit their fitness needs.

If you agree to participate, you will be asked to answer a questionnaire where you will use your experiences with your chosen exercise program to answer the questions. It will take approximately ten (10) minutes of your time to answer this online questionnaire.

Your part in this study is anonymous. That means your answers are private. No one else can know if you participated in this study and no one else can find out what your answers were. Scientific reports will be based on group data and will not identify you or any individual as being in this project. On data sheets your scores will be identified by a subject identification number. The questionnaires will only be seen by the authors of this study. You may provide an email address separate from your questionnaire at the end to be put into a drawing for $20 VISA gift cards to go toward a fitness membership. Once contact of the winners has occurred, all email addresses will be discarded by the main author.

Risks: Minimal risk is expected. The questionnaire may bring up memories of past, potentially troublesome experiences associated with exercise. Such as if a participant had poor commitment or motivation to stay with the exercise program and stopped exercising. Feelings of anxiety, anger or helplessness may be brought up due to memories of a previous injury due to a prior exercise program. If this is the case, you may contact the researcher (Bryanne Bellovary) to discuss options, such as contacting a local behavior health specialist.

Benefits: It is hoped you will feel empowered to share your thoughts about your exercise habits and any negative or positive outcomes so that future exercisers in various exercise programs will be better prepared to handle the workout load.

Taking part in this research study is completely voluntary. You will be expected to answer honestly on the questionnaire. If you decide to discontinue participation in this study, you can submit the questionnaire as incomplete.

If you have any further questions regarding your rights as a participant in a research project you may contact Dr. Brian Cherry of the Human Subjects Research Review Committee of Northern Michigan University (906-227-2300) bcherry@nmu.edu. Any questions you have regarding the nature of this research project will be answered by the principal researcher who can be contacted as follows: Bryanne Bellovary (906-227-2130) bbellova@nmu.edu or Dr. Scott Drum at 906-227-2195 or sdrum@nmu.edu.

I have read the above "Informed Consent Statement." The nature, risks, demands, and benefits of the project have been explained to me. I understand that I may ask questions and that I am free to withdraw from the questionnaire at any time without incurring ill will or negative consequences. I also understand that my questionnaire answers will be kept anonymous and if I choose to provide an email address to be entered into the drawing these will be kept separate from the questionnaire and be kept confidential. Access to this document is restricted to the principle investigators.

If you choose to accept the above terms and conditions please click "next" below to start the questionnaire.

Thank you very much for your consideration.

Sincerely,
Bryanne Bellovary

Graduate Student
School of Health, Physical Education and Recreation
Northern Michigan University

APPENDIX G

INFORMED CONSENT FORM RELIABILITY TESTING

To whom this may concern,

We are inviting you to participate in a research study. The purpose of the study is to compare exercise training programs based on past experiences of their participants. Questions will cover areas concerning your general exercise training background and your perceived intensity of the training program(s).

We are inviting you to be in this study because you are currently participating in an exercise program at the gym of your choosing. Our hope is that you will help provide further insights into your fitness program for future participants to use as they decide the best program to suit their fitness needs.

If you agree to participate, you will be asked to answer a questionnaire on two separate dates with about two weeks in between where you will use your experiences with your chosen exercise program to answer the questions. It will take approximately ten (10) minutes of your time to answer this online questionnaire for each session.

Your part in this study is anonymous. That means your answers are private. No one else can know if you participated in this study and no one else can find out what your answers were. Scientific reports will be based on group data and will not identify you or any individual as being in this project. On data sheets your scores will be identified by a subject identification number. The questionnaires will only be seen by the authors of this study. You may provide your name separate to your questionnaire at the end for two (2) points of extra credit in the class you are enrolled in with the instructor, Bryanne Bellovary. If you choose to not participate in the study, please inform the instructor and she will provide you with an alternate two (2) point extra credit opportunity.

Risks: Minimal risk is expected. The questionnaire may bring up memories of past, potentially troublesome experiences associated with exercise. Such as if a participant had poor commitment or motivation to stay with the exercise program and stopped exercising. Feelings of anxiety, anger or helplessness may be brought up due to memories of a previous injury due to a prior exercise program. If this is the case, you may contact the researcher (Bryanne Bellovary) to discuss options, such as contacting a local behavior health specialist.

Benefits: It is hoped you will feel empowered to share your thoughts about your exercise habits and any negative or positive outcomes so that future exercisers in various exercise programs will be better prepared to handle the workout load.

Taking part in this research study is completely voluntary. You will be expected to answer honestly on the questionnaire. If you decide to discontinue participation in this study, you can submit the questionnaire as incomplete.

If you have any further questions regarding your rights as a participant in a research project you may contact Dr. Brian Cherry of the Human Subjects Research Review Committee of Northern Michigan University (906-227-2300) bcherry@nmu.edu. Any questions you have regarding the nature of this research project will be answered by the principal researcher who can be contacted as follows: Bryanne Bellovary (906-227-2130) bbellova@nmu.edu or Dr. Scott Drum at 906-227-2195 or sdrum@nmu.edu.

I have read the above "Informed Consent Statement." The nature, risks, demands, and benefits of the project have been explained to me. I understand that I may ask questions and that I am free to withdraw from the questionnaire at any time without incurring ill will or negative consequences. I also understand that my questionnaire answers will be kept anonymous. If I choose to provide my name to receive extra credit from taking the questionnaire, my name will be kept separate from the data collected and kept confidential. I also understand that if I choose to not participate in this study, I can be given an alternate extra credit assignment without consequence. Access to this document is restricted to the principle investigators.

If you choose to accept the above terms and conditions please click "next" below to start the questionnaire.

Thank you very much for your consideration.

Sincerely,
Bryanne Bellovary

Graduate Student
School of Health, Physical Education and Recreation
Northern Michigan University