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Graduate Studies

ENERGY COST AND RELATIVE INTENSITY OF THE KETTLEBELL WORKOUT

**A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the
Degree of Master of Science**

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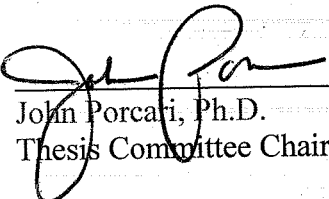
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ENERGY COST AND RELATIVE INTENSITY OF THE KETTLEBELL WORKOUT

By Chad W. Schnettler

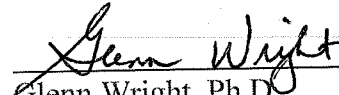
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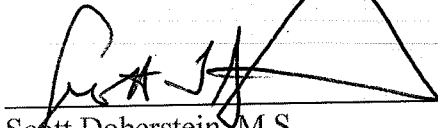
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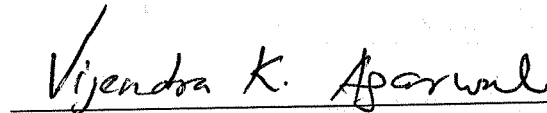
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ABSTRACT

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This study was designed to evaluate the exercise intensity and energy expenditure of a typical kettlebell workout. Ten subjects (8 males, 2 females) completed treadmill VO_2max test to determine their aerobic capacity. Subjects then performed a 5-minute kettlebell VO_2max snatch test. Heart rate (HR) and oxygen consumption (VO_2) were measured and a HR/ VO_2 regression equation was determined. Subjects performed a 20-minute intermittent kettlebell snatch workout that consisted of 15 seconds of kettlebell snatch followed by 15 seconds of rest. Only HR was measured. There was a significant difference ($p < .05$) for VO_2max values between the treadmill VO_2max test and the kettlebell VO_2max snatch test (49.7 ± 6.6 vs. 40.3 ± 2.2 , respectively). No significant difference was found for maximal HR values between the two tests (180 ± 8.5 vs. 176 ± 12.5 bpm). Average HR for the kettlebell snatch workout was 164 ± 14.7 bpm ($93 \pm 4.5\%$ of kettlebell VO_2max snatch test HRmax) and average VO_2 was 31.6 ± 3.71 ml/kg/min ($78 \pm 8.0\%$ of VO_2max) as determined by the HR/ VO_2 regression equation. Average caloric expenditure was 13.6 ± 3.08 kcal/min. The results show that the kettlebell snatch workout meets ACSM guidelines for exercise intensity and duration. Energy expenditure was likely underestimated due to the inability to accurately calculate anaerobic energy expenditure.

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I would like to extend a sincere thanks to all of those people who were willing participants in my study. I can't thank them enough for being flexible with their schedules in order to take the time to help contribute to this study. All of you were a pleasure to work with and it was great to have the opportunity to get to know all of you to some degree.

Another thank you goes out my thesis advisor Dr. John Porcari and all of my committee members. Your guidance along the way helped me realize what goes into conducting and writing a successful research project.

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INTRODUCTION

When getting started on an exercise program, many people immediately look to any one of the number of innovative or fad workouts that exist. Often times these workouts claim to give people greater results in a considerably shorter amount of time than a traditional workout by incorporating a variety of movements into the training. Many of these workouts seek to seamlessly intertwine both aerobic and resistance training, with the knowledge that resistance training is almost always included in any effective exercise program. One workout that seeks to take advantage of this idea is the kettlebell workout, which is a phenomenon that has just reached the United States in recent years by way of Russia. A kettlebell is a resistance device that looks like a cannonball with a big, broad handle attached to it and is typically made of solid cast iron. It is used as the resistance to perform a variety of movements, many of which incorporate a large number of muscle groups and are multi-joint lifts.

Even though there has been very little to no research directly related to the kettlebell workout, there are a number of other studies evaluating the energy cost of similar workouts. Wilmore et al. (1978) observed the energy cost of circuit weight training (CWT), finding that on average men burned 202 calories per session and women burned 138 calories during each 22.5 minute CWT workout. They also found that subjects worked at 84% of heart rate maximum (HRmax) and 45% of maximal oxygen consumption (VO₂max). In a follow up to Wilmore's study, Garbutt et al. (1994)

discovered similar results with CWT, with subjects working at 69% of HRmax and 50% of VO₂max during the study. Both of these studies found it interesting that subjects worked at such a high % of HRmax, but a low % of VO₂max.

While examining the effects of the Body Pump workout (an aerobic workout utilizing barbells as resistance), Stanforth et al. (2000) found that subjects worked at an average of 29% of VO₂max and 63% of HRmax. Subjects burned 265 calories over the 45-60 minute workout. Olson et al. (1991) studied the effects of bench stepping exercise in females and found that the use of two pound hand weights during exercise significantly increased VO₂, caloric expenditure, and ratings of perceived exertion (RPE), even when compared to the use of one pound hand weights. They also found that upper body exercise elicited higher HR and lower stroke volume values than leg exercise at the same VO₂. These differences relate to a phenomenon called the "pressor response."

Porcari and Curtis (1996) reviewed the pressor response, a concept that results in a disproportionately elevated HR when compared to oxygen consumption during resistance training. The pressor response phenomenon is made up of three key components. First, this response activates areas of the brain that control cardiovascular function by attempting to have HR and blood pressures match the number of electrical impulses received by the working muscles. Second, muscular contraction causes compression of the blood vessels that lead to the working muscle, inhibiting fresh blood from reaching the tissue beds while also not allowing waste products to be removed from the working areas. This results in HR and blood pressure being regulated by a nervous reflex that doesn't necessarily meet the metabolic needs of the muscle. Third,

vasoconstriction also occurs in the non-working muscles in an attempt to redirect blood to the working muscles. This reduces the heart's stroke volume and increases HR.

The purpose of this study was to determine the energy cost and relative exercise intensity of a typical kettlebell workout. The effectiveness of the workout was also compared to recommendations outlined by the American College of Sports Medicine (ACSM) for improving cardiorespiratory endurance and positively affecting body composition. To our knowledge, the only research performed on kettlebell exercise has been conducted in Russian, and study results are not available in the English language.

METHODS

Subjects

The subjects in this study were 10 apparently healthy adults (eight males and two females) that were experienced in kettlebell training. The subjects were recruited through direct contact with kettlebell certified instructors in and around the area of La Crosse, WI.

Protocol

After approval to perform the study from the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects, subjects provided informed consent prior to the completion of any testing procedures. An initial maximal treadmill test was performed in the Human Performance Laboratory in Mitchell Hall in order to determine the HR_{max} and VO₂ of the subjects. The test was conducted using the Bruce protocol. During this test, HR was measured using a Polar monitor (manufacturer info) and oxygen consumption was measured using an AEI metabolic system (manufacturer info). Ratings of perceived exertion were also assessed during each stage and at maximal exertion using the Borg 6-20 scale. Blood lactate was taken exactly three

minutes following the conclusion of the test using the finger prick method. This test was used as a basis to determine the HR/ VO_2 relationship of the subjects during typical aerobic exercise.

After completion of the maximal treadmill test, all subjects returned to the Human Performance Laboratory on a separate day to perform a kettlebell VO_2 max snatch test (2008). During this test, the subjects used either a 12, 16, or 20 kg kettlebell depending on their gender, body weight, fitness level, and experience level using kettlebells. The test lasted for five minutes, with the subject continuously performing snatches to a specific cadence during each minute. Every minute the subject switched the kettlebell to their other hand until the five minutes were completed. The subject started with the kettlebell in their dominant hand. For example, if the subject was right-handed, they performed minutes 1, 3 and 5 with their right hand and minutes 2 and 4 with their left hand. The cadence sequence for the workout is defined below:

- First minute: 8 repetitions at a rate of 1 snatch every 7 seconds.
- Second minute: 12 repetitions at a rate of 1 snatch every 5 seconds.
- Third minute: 15 repetitions at a rate of 1 snatch every 4 seconds.
- Fourth minute: 20 repetitions at a rate of 1 snatch every 3 seconds.
- Fifth minute: The subject went all out, performing as many snatches as they could until they fatigue.

The number of snatches successfully completed during the final minute of the kettlebell snatch workout was counted and applied to the kettlebell snatch workout.

During the kettlebell test, HR and VO_2 were measured during each stage using the same procedures as the treadmill test. A peak RPE value was taken following completion of the

test. Blood lactate was taken three minutes following the completion of the test using the finger prick method. Following data collection, a regression equation to predict VO_2 was developed from the HR and VO_2 data.

Following the maximal kettlebell test, subjects then performed a 20-minute kettlebell snatch workout. This workout took place on a separate day and required the subjects to perform a specific number snatches every 15 seconds in accordance with the number of snatches they completed during the final minute of the kettlebell snatch test. For example, if a subject completed 24 snatches during the final minute, this number was divided by four and they were required to complete at least six snatches during each timed 15 second period. If the subjects were able to complete more snatches during the 15 second period, they were strongly encouraged to complete as many snatches as they were able to in the 15 second period.

The test started out with the subjects completing a non-specific warm-up, preparing as they normally would for a bout of kettlebell training. The exercise portion of the test started out with the subject performing one-armed kettlebell snatches with their dominant hand for 15 seconds. They were then given a 15 second rest period and performed another 15 seconds of snatches using their other hand. Another 15 second rest period was given and they switched the kettlebell back to their dominant hand. This sequence of 15 seconds of snatches and 15 seconds of rest continued for 20 minutes, with the subjects alternating hands for each bout of snatches. The workout concluded with a non-specific cool-down period lasting for five minutes. During this visit, only HR was measured so that there was no restriction of movement during the workout. HR values were collected at the end of each minute during the 20-minute workout. An average HR

was determined for each subject by summing the minute-by-minute HRs recorded during the 20-minute training session. Blood lactate was taken immediately following completion of the 20-minute snatch workout.

For all tests, subjects were asked to refrain from performing any maximal exertion at least 48 hours prior to any of the three tests. At least 48 hours of rest was given to each subject before another test was performed, with ideally no more than a week of rest given in between any of the three tests.

STATISTICAL METHODS

Standard descriptive statistics were used to calculate the means and standard deviations for the data collected. A paired samples t-test was used to compare the maximal HR and VO_2 for the kettlebell snatch test and the treadmill test. SPSS version 13 was used to determine the regression equations used to calculate average VO_2 for the kettlebell snatch workout. Alpha was set at .05 to achieve statistical significance.

RESULTS

All 10 subjects completed the three phases of the testing protocol. The descriptive characteristics of the subjects used in the final analyses of the study are presented in

Table 1.

Table 1. Demographic characteristics of study subjects (N = 10)

	Mean \pm SD	Range
Age (years)	36.9 \pm 5.9	29.0 – 46.0
Height (inches)	68.9 \pm 4.1	62.0 – 73.0
Weight (lbs)	191.1 \pm 36.8	132.0 – 257.0

Maximal HR and VO₂ values were compared for the maximal treadmill and kettlebell VO₂max tests. A significant difference was found value between the VO₂max of the treadmill test and the kettlebell VO₂max test. The treadmill VO₂max was 23% higher than the VO₂max attained during the kettlebell VO₂max test. No significant difference was found between the maximal HRs attained during either test. The maximal HR and VO₂ values from the maximal treadmill test and kettlebell snatch test are presented in Table 2.

Table 2. Maximal HR and VO₂ values from the maximal treadmill test and kettlebell snatch test

	Mean ± SD	Range
Treadmill VO ₂ max (ml/kg/min)	49.7 ± 6.6	42.8 – 65.5
Kettlebell VO ₂ max (ml/kg/min)	40.3 ± 2.2*	36.5 – 43.2
Treadmill HRmax (bpm)	180 ± 8.5	171 – 195
Kettlebell HRmax (bpm)	176 ± 12.5	148 – 191

* Significantly lower than the treadmill VO₂max value (p < .05)

Average HR values during the kettlebell snatch workout were between 86 and 99% of the kettlebell HRmax for all subjects. VO₂ values were obtained by inserting the average HR values for the kettlebell snatch workout into the regression equation developed from the kettlebell VO₂max test. The average HR, VO₂, and caloric expenditure values for the kettlebell snatch workout are presented in Table 3.

Table 3. Average HR, VO₂, and caloric expenditure values for the kettlebell snatch workout. All HR and VO₂ values are compared to maximal values measured during the kettlebell snatch test.

	Mean \pm SD	Range
HR (bpm)	164 \pm 14.7	128 – 180
% HRmax	93 \pm 4.5	86 – 99
VO ₂ (ml/kg/min)	31.6 \pm 3.71	24.6 – 36.6
% VO ₂ max	78 \pm 8.0	67 – 91
Kcal/min	13.6 \pm 3.08	8.75 – 17.85
Peak RPE	15.9 \pm 2.21	10 – 18

HR response of the subjects during each minute of the kettlebell snatch workout is presented in Figure 1. It took ~9 minutes to reach a steady state HR during the kettlebell workout.

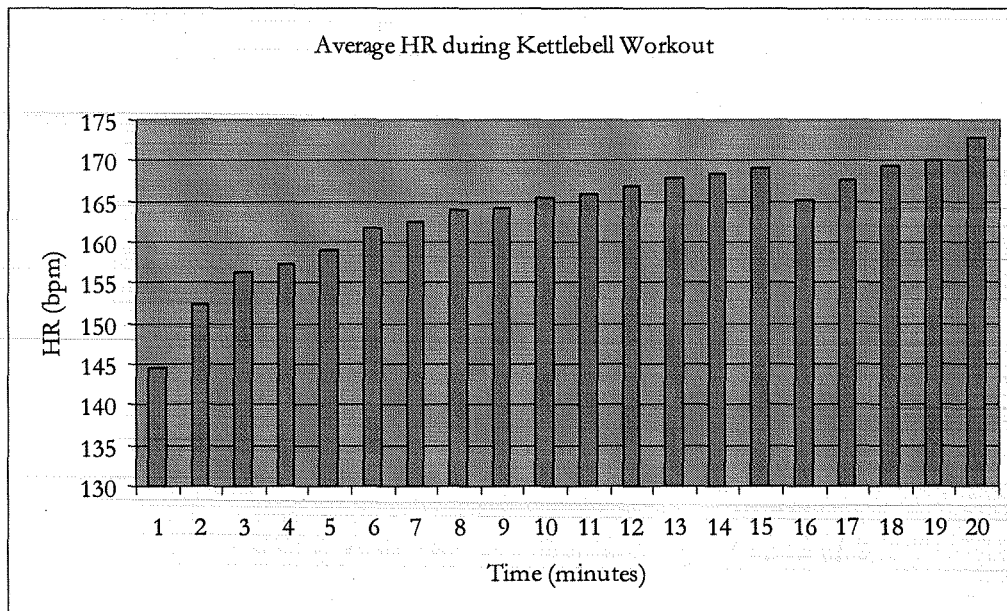


Figure 1. Average HR of subjects during each minute of the kettlebell snatch workout

An overall HR/VO₂ regression equation was developed using the data from all subjects to illustrate the difference in this relationship between kettlebell exercise and treadmill exercise. This comparison of HR/VO₂ between the maximal treadmill test and the kettlebell snatch test is presented in Figure 2.

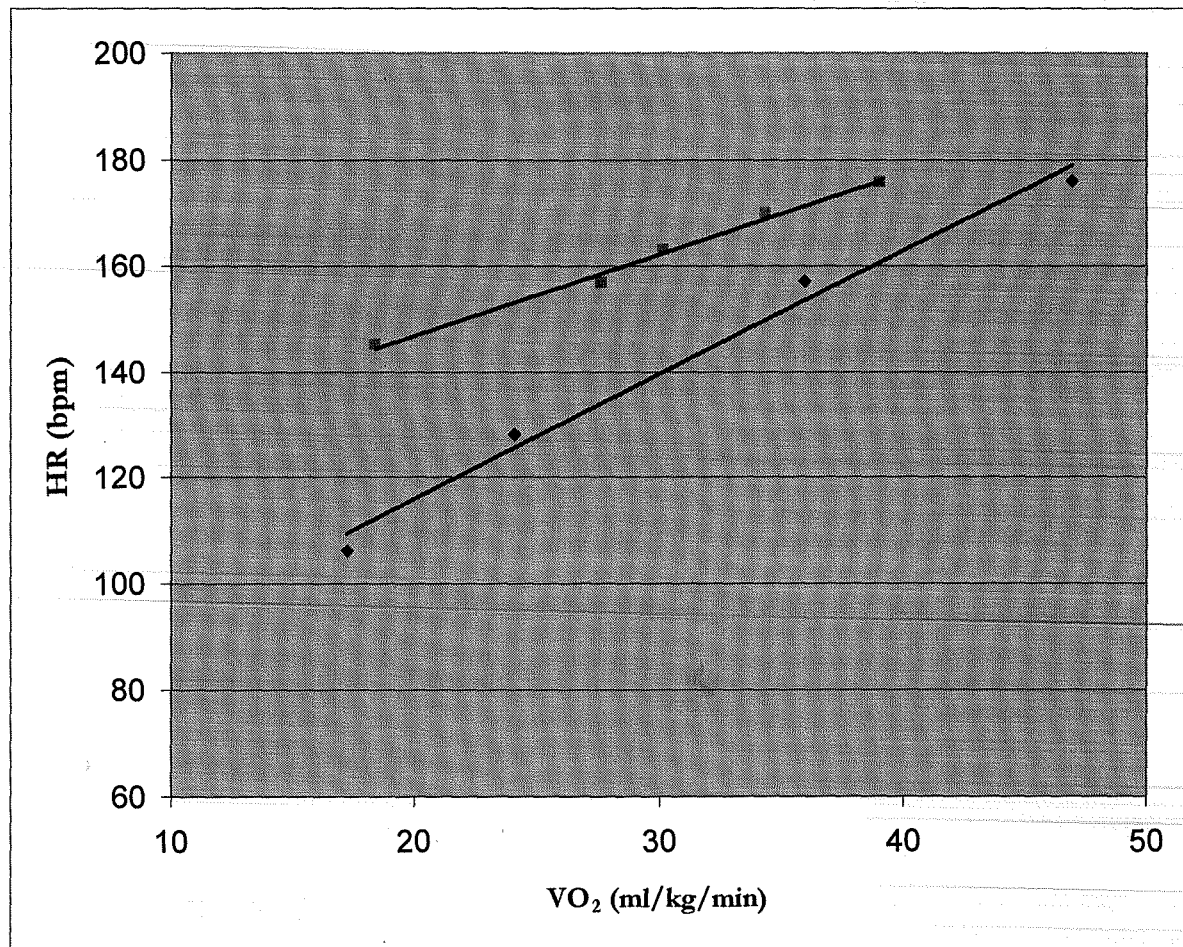


Figure 2. Comparison of HR/VO₂ relationship between the maximal treadmill test and the kettlebell snatch test (diamonds = maximal treadmill test, squares = kettlebell VO₂max test).

Lactate values were measured three minutes after the maximal treadmill test, three minutes after the kettlebell snatch test, and immediately after completing the 20-minute kettlebell snatch workout. The lactate value following the maximal treadmill test was 14.1 ± 4.8 mmol. The lactate value following the kettlebell snatch test was 8.9 ± 4.0 mmol. The lactate value immediately following the kettlebell snatch workout was 7.8 ± 3.6 mmol.

DISCUSSION

The main purpose of this study was to determine the energy cost and relative intensity of a typical kettlebell workout. The study also aimed to quantify how the HR and VO_2 data obtained during the kettlebell snatch workout compared to the guidelines recommended by the ACSM for improving cardiorespiratory endurance. The ACSM (2006) recommends that healthy adults exercise at an intensity of 64% - 94% of HRmax or 40% - 85% of VO_{2max} to improve aerobic capacity. The kettlebell snatch workout meets these recommendations, as HR averaged 93% of HRmax and VO_2 averaged 78% of VO_{2peak} when compared to the kettlebell VO_{2max} test (63% of VO_{2max} when compared to the maximal treadmill test).

The HR and VO_2 responses during the kettlebell snatch workout indicated a much greater intensity than other studies that incorporated weights or weight training into the workout. However, the one common thread between the studies is a significant difference between % HRmax and % VO_{2max} values. During the Body Pump workout (1991), subjects worked at only 29% of VO_{2max} , but 63% of HRmax. Similar differences were also seen in studies by Wilmore, et al. (1978) and Garbutt et al. (1994). The subjects in the study by Wilmore et al. (13) worked at 84% of HRmax and only 45% VO_{2max} during

CWT. The subjects in the study by Garbutt et al. (1994) worked at 69% of HRmax and 50% of VO₂max, also performing a CWT workout. The discrepancy between % of HRmax and % of VO₂max to varying degrees in all of these studies indicates that a pressor response was occurring. Given that the difference between % HRmax and %VO₂max was less for the kettlebell snatch workout than in these other studies, it would indicate that the kettlebell snatch workout is more aerobic than the training methods used in other studies. This is likely because a greater muscle mass is active during kettlebell exercise. Larger muscles mean a greater distribution of blood flow.

One primary reason for activation of the pressor response with the kettlebell snatch workout was that even though correct technique for kettlebell snatches does involve the legs, much of the work is actually accomplished using the shoulder muscles. Because of the heavy weights used during the workout, the muscles are likely working at a relatively higher percentage of their maximum (% maximal voluntary contraction), thus invoking a high pressor response. A higher HR at any given level of VO₂ is typically seen with arm work compared to leg work. This relationship was also evident in Figure 2, where the HR/VO₂ relationship for the kettlebell snatch test and the treadmill test were predicted.

ACSM recommends an exercise duration of 20-60 minutes of moderate intensity exercise in order to produce cardiorespiratory benefits. However, new guidelines published by ACSM and the American Heart Association (2007) state that 20 minutes of vigorous aerobic activity is also acceptable in order to promote and maintain physical health. The kettlebell snatch workout falls within these new guidelines, as the kettlebell snatch workout would be considered vigorous exercise.

Caloric expenditure is also another important factor that was determined. In the study by Wilmore et al. (1978), the subjects burned an average of 138 calories during the 22.5 minute CWT workout. During the Body Pump workout (2000), subjects burned an average of 265 calories over the 45-60 minute workout. The data collected for the kettlebell snatch workout indicated that subjects burned an average of 13.6 kcal/min. This translated to an average aerobic energy expenditure of 272 calories during the 20-minute workout. According to McArdle et al. (1996), in a 190 lb individual (the mean weight of study subjects), this rate of energy expenditure is comparable to cycling at a rate of 15 mph or running at a 9-minute mile pace. However, our study likely underestimated the actual energy expenditure as we were unable to develop an accurate method for calculating anaerobic energy expenditure with the data we had collected. Anaerobic energy expenditure also has a significant impact on the rate at which calories are burned.

A limitation to this study was that we were not able to collect blood samples for blood lactate analysis during the kettlebell workout. Since we were extrapolating oxygen consumption from HR response, we felt that any delay in the 15 sec work/15 sec rest intervals would not allow the maintenance of a sustainable HR response.

It is known that repeated high-intensity work bouts with short rest periods have a progressive increase in oxygen uptake. Tabata et al. (1997) used a high-intensity repeat sprint cycling (~170% VO₂ max) protocol using 20 sec work/10 sec rest and found that this type of protocol taxes aerobic and anaerobic energy systems maximally after 6-7 repeats. Although the kettlebell protocol was not performed at this high of intensity, we suggest that the post-exercise blood lactate value of 7.8 mmol indicates a large anaerobic energy expenditure was utilized.

It is also possible that the blood lactate value measured post-exercise may be an underestimate of the anaerobic contribution during the 20-minute kettlebell protocol. It is likely that at the beginning of the kettlebell workout, because of the nature of the task and the existence of an oxygen deficit period, the sympathetic stimulus and related epinephrine release into the blood increased muscle glycogenolysis as stated in the text by Brooks et al. (2005). The text by Brooks et al. (2005) also verifies that this feed-forward regulation of glycolysis rapidly increases the available pyruvate to the mitochondria in the muscle cells. Any delay in oxygen consumption or stimulation of pyruvate dehydrogenase in the mitochondria will lead to an increased production of lactate in the muscle and removal to the blood. In addition, the nature of the kettlebell workout (explosive, large muscle mass activity) would likely recruit an abundant number of Type II (fast) motor units as discussed in the text by Brook et al. (2005). These type II motor units are known for a higher production of lactate since mitochondrial density is low in this fiber type as evidenced in the study by Ivy et al. (1980).

Scott (2006) utilized a conversion whereby every 1 mmol of lactate was equivalent to 3 ml/kg/min of oxygen consumption. Given this conversion, the 7.8 mmol of lactate measured on average immediately following the kettlebell snatch workout subtracted by the 2.8 mmol of lactate at rest would have translated into an additional 15.2 ml/kg/min of oxygen consumption. With this data available, the anaerobic energy expenditure was likely 6.6 kcal/min and would have contributed an additional 132 calories for the entire 20-minute workout.

As the duration of kettlebell workout and oxygen consumption in the muscle increased, it is also likely that a portion of the lactate produce was removed from the

blood as a result of the lactate shuttle proposed in the text by Brooks et al. (2005). This mechanism involves the uptake of lactate from the blood to oxidative tissues, including Type I muscle fibers and heart myocardium, where it is used as a fuel for aerobic production of adenosine triphosphate. An increased uptake of lactate from the blood during the second half of the kettlebell workout would lead us to speculate that our post exercise blood lactate value is likely a low representation of blood lactate accumulation during the kettlebell workout. Our data for blood lactate indicates a substantial contribution of energy provision by the anaerobic energy systems during the kettlebell workout, and although we were not able to quantify this contribution accurately with a lack of sampling times, we cannot ignore the contribution of these systems when considering the total energy expenditure of the kettlebell workout.

Even though the results attained during the study were what were expected, there were a number of limitations that may have impacted results. One limitation is that the experience level of the subjects varied significantly. Some subjects had only been training with kettlebells for 2-3 months, while others had been training for upwards of 3 years. This may have impacted the rate at which certain subjects fatigued, as some subjects were much more acclimatized to kettlebell training than others.

Another limitation was the lack of standardized warm-up and cool-down periods. Subjects were allowed to prepare as they normally would for a typical kettlebell workout. Since they were all currently involved in training with kettlebells, this resulted in varying times it took for some subjects to complete the warm-up period.

In the case of four subjects, the kettlebell snatch workout was completed in a garage with a temperature of 50 degrees Fahrenheit. This may have altered HR data

slightly as cold conditions can stimulate vasoconstriction of vessels. However, this was done in order to allow the greatest convenience possible to the subjects. Given that they always perform their workouts in this facility, they were accustomed to these conditions.

The final limitation that can be noted is that the kettlebell snatch workout represents only one of numerous kettlebell workouts available. The kettlebell snatch workout was selected on the basis that it would best correlate with the data collected during the kettlebell snatch test. Future studies could focus on other kettlebell exercises and could select to increase or decrease the duration of the workout.

CONCLUSION

In conclusion, the kettlebell snatch workout meets the ACSM guidelines for improving cardiorespiratory endurance. The 20-minute kettlebell snatch workout also meets ACSM and AHA recommendations for exercise intensity as it is considered vigorous intensity. However, the high HRs reached during the workout indicate the pressor response was activated due to the large volume of work being done with the arms as opposed to the legs.

Energy expenditure during the kettlebell snatch workout averaged 13.6 kcal/min or 272 calories burned during the 20-minute workout. This number is likely an underestimate of total energy expenditure as anaerobic energy expenditure played a significant role. Lactate samples were not taken during the kettlebell snatch workout when lactate levels were likely highest in the blood.

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APPENDIX A
INFORMED CONSENT

Protocol Title: Energy Cost and Relative Intensity of the Kettlebell Workout

Principal Investigator: Chad Schnettler
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- **Purpose and Procedure**
 - The purpose of this study is to determine the energy cost and relative exercise intensity of the kettlebell workout.
 - My participation will involve three tests, all of which may cause extreme fatigue. The first test will be a maximal treadmill test, the second a kettlebell VO₂max test, and the third a typical kettlebell workout routine.
 - The total time requirement is three to four hours total, divided between three separate occasions, with at least 48 hours between testing periods.
 - Testing will take place in room 225 Mitchell Hall, on the UW-L campus.
 - During the maximal treadmill and kettlebell VO₂max tests I will wear a mouthpiece and headgear in order to analyze my oxygen consumption and a Polar heart rate monitor, wrapped around my chest, to monitor my heart rate. During the kettlebell workout I will only wear a Polar heart rate monitor. I will also have my finger pricked in order to get blood lactate values.
- **Potential Risks**
 - I may experience substantial overall muscle fatigue and soreness.
 - Pulled muscles and other minor injuries may occur as with any other resistance training workout.
 - I will experience a small amount of blood loss as a result of having my finger pricked to measure blood lactate values.
 - Individuals trained in CPR, Advanced Cardiac Life Support, and First Aid will be in the laboratory, and the test will be terminated if complications occur.
 - The risk of serious or life-threatening complications, for healthy individuals, life myself, is nearly zero.
- **Rights and Confidentiality**
 - My participation is voluntary.

- I can withdraw from the study at any time for any reason without penalty.
- The results of this study may be published in scientific literature or presented at professional meetings using grouped data only.
- All information will be kept confidential through the use of numbered codes. My data will not be linked with personally identifiable information.
- **Possible Benefits**
 - I and any other person that incorporates resistance training into a workout may benefit by knowing the energy cost and relative intensity of the kettlebell workout and how the findings relate to the guidelines outlined by the American College of Sports Medicine.

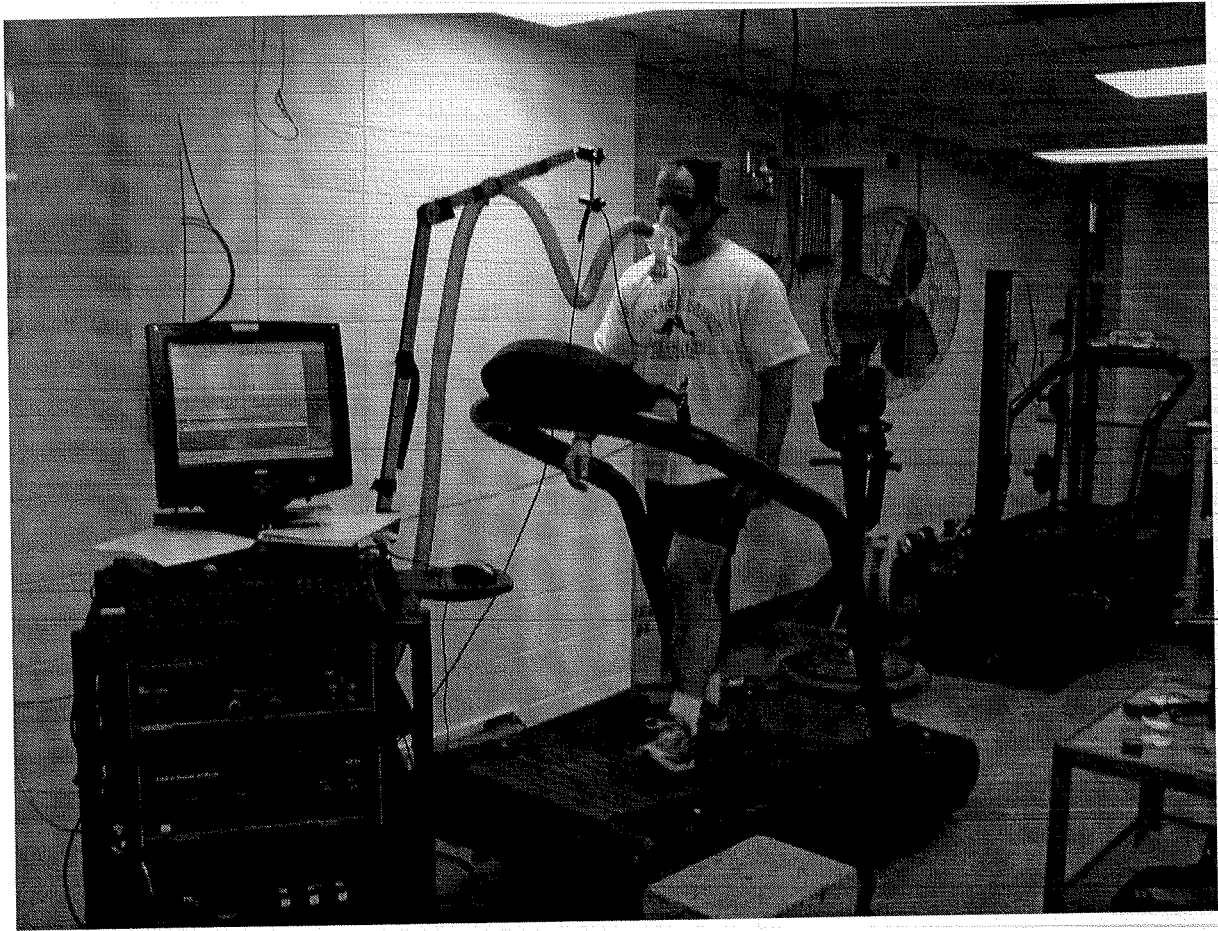
Questions regarding study procedures may be directed to Chad Schnettler (320-224-3967), the principal investigator, or the study advisor Dr. John Porcari, Department of Exercise and Sports Science, UW-L (608-785-8684). Questions regarding the protection of human subjects may be addressed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects (608-785-8124 or irb@uwlax.edu).

Participant _____ Date _____

Researcher _____ Date _____

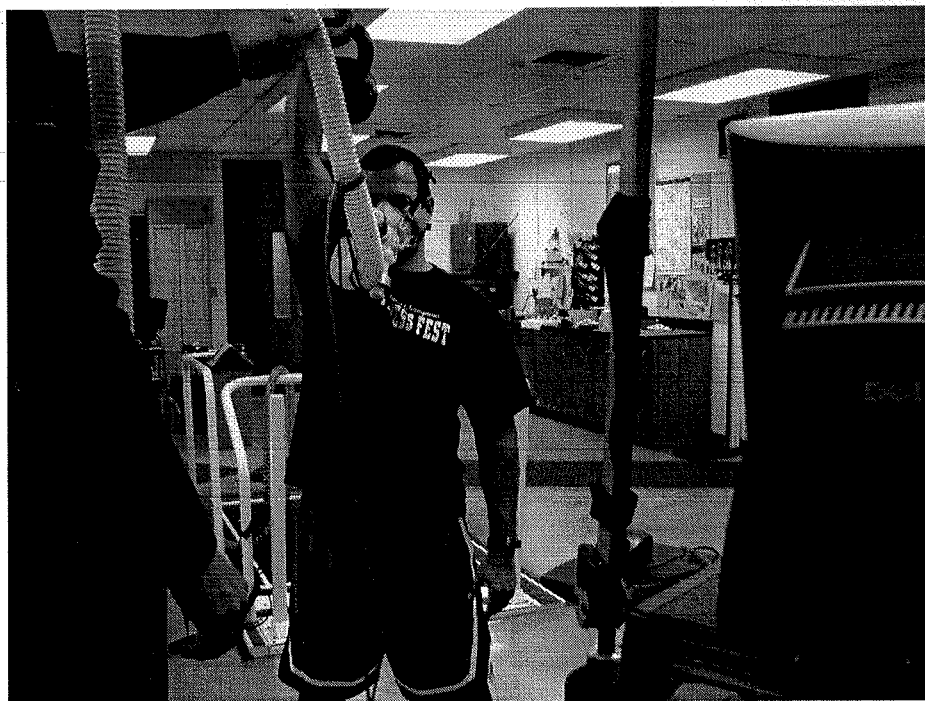
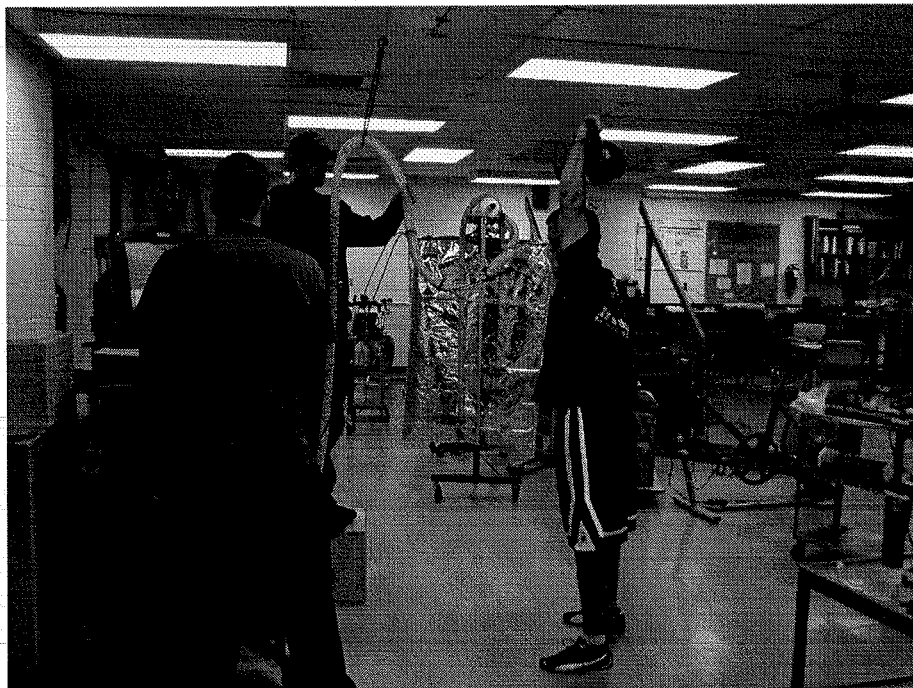
APPENDIX B

PHOTO OF SUBJECT PERFORMING MAXIMAL TREADMILL TEST



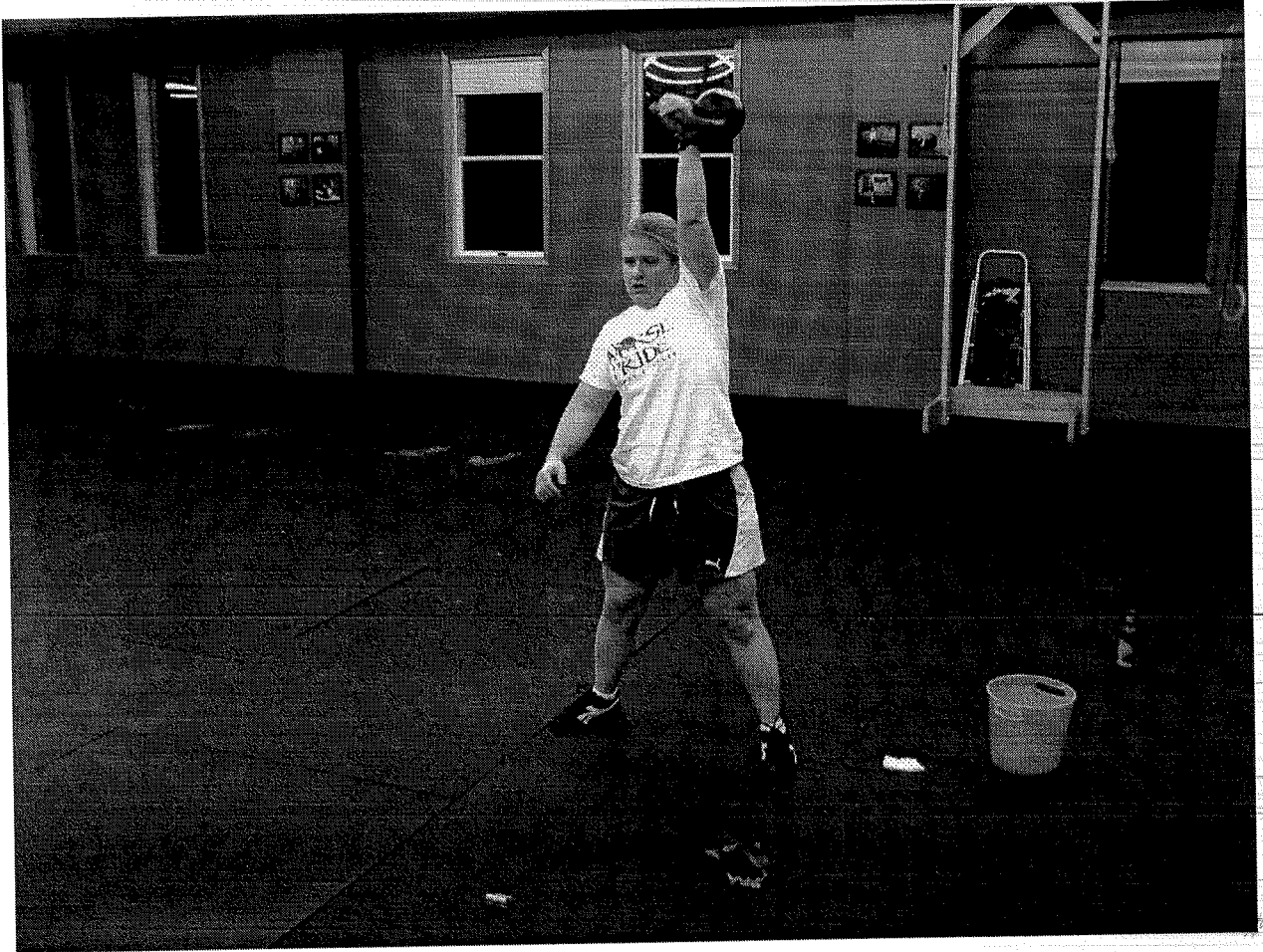
APPENDIX C

PHOTOS OF SUBJECT PERFORMING KETTLEBELL SNATCH TEST



APPENDIX D

PHOTO OF SUBJECT PERFORMING KETTLEBELL SNATCH WORKOUT



APPENDIX E

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The purpose of this paper is to review the existing literature concerning studies that have been performed to assess the energy cost and relative intensity of resistance training workouts or other workouts with similarities to the kettlebell workout. Despite the recent emergence of the use of kettlebells, no research has been done directly assessing its energy cost and relative intensity.

Overview of Exercise Recommendations

According to the American College of Sports Medicine (ACSM) (1998), the need for maintaining muscular strength and endurance is highly recommended. The guidelines for resistance training are to perform at least one set of 8-10 exercises that work the major muscle groups 2-3 days per week. Each set should be comprised of approximately 8-12 repetitions. ACSM (2006) recommendations for improving and maintaining cardiorespiratory fitness are training 3-5 days per week at an intensity of 64-94% maximum heart rate (HR_{max}) or 40-85% of maximum oxygen uptake (VO₂ max). Haskell et al. (2007) state that the duration of activity should last for 20-60 minutes of moderate intensity continuous aerobic activity with the selected exercise targeting most major muscle groups. Twenty minutes of vigorous intensity aerobic activity also meets these guidelines.

Intensity of Related Workouts

Stanforth et al. (2000) examined the physiological and metabolic responses to a Body Pump workout. This is a workout program that utilizes barbells and weight plates in a group exercise setting while performing the movements to different music tracks. Typically, a Body Pump workout will be divided into 9 tracks, each lasting for 5-7

minutes and targeting specific muscle groups within the body. Typically each track will include about 100 repetitions. The subjects in this study were 15 males and 15 females who completed Body Pump workouts prior to testing to familiarize themselves with the movements in the workout. A maximal treadmill test was performed to determine baseline values for a variety of measurements. During the testing period, oxygen consumption (VO_2), heart rate (HR), and rating of perceived exertion (RPE) were measured. Body composition was also measured via hydrostatic weighing. The subjects worked at an average of 29% of VO_{2max} and 63% of HR_{max} while burning an average of 265 calories during the hour long workout. The average RPE was 15.3. The researchers discovered that the aerobic intensity of a Body Pump workout is less than the intensity recommended by ACSM. Lower body or combined lower body/upper body exercises have a much higher VO_2 than the exercises focusing primarily on upper body movements. Another interesting finding was that due to the high RPE values, it would have been difficult to increase the intensity of the workout.

Wilmore et al. (1978) studied the energy cost of circuit weight training (CWT). The subjects were 20 men and 20 women, all within the ages of 17-36 years and familiar with CWT. The study had subjects perform a 5-minute warm up, then the 22.5 minute CWT routine, followed by a 12-minute recovery period. The results showed that men burned an average of 202 calories while the women expended 138 calories during the CWT routine. The subjects worked at an intensity of 84% of HR_{max} , but only 45% of VO_{2max} . The researchers found the great discrepancy between % HR_{max} and % VO_{2max} to be quite curious.

In a similar study, Garbutt et al. (1994) also evaluated the physiological responses to a CWT workout. This study included 10 subjects who performed a maximal treadmill test prior to the testing period to determine baseline values for a variety of measurements. The testing was done with subjects using weight that corresponded to 40% of one repetition maximum (1RM). The circuit was performed three times and included nine different exercises that focused on isolating all major muscle groups. Each leg exercise was performed 10 times per set and arm and trunk exercises 15 times per set. There was 30 seconds of rest in between sets. During the testing, the subjects were working at an average of 69% of HRmax and 50% of VO₂max. The researchers found that the target HR of 60% maximum was achieved, but the target VO₂ of 50% maximum was only achieved during the third circuit. They also found that HR was greater for arm exercises than exercises that combined arm and leg movements.

Hunter et al. (2003) evaluated the metabolic and HR responses to super slow training (SST) vs. traditional resistance training (TT). SST is a popular new resistance training concept that utilizes 15 second contractions. The concentric phase of each contraction is 10 seconds and the eccentric phase is 15 seconds. The study utilized 7 male recreational weight lifters. SST included one set of 8 repetitions, while TT utilized 2 sets of 8 repetitions for each exercise. SST used only 25% of 1RM and TT was done with 65% of 1RM, with each workout lasting for 29 minutes. The results indicated that TT had a higher net VO₂, HR, blood lactate, and energy expenditure than SST.

Hepple et al. (1997) analyzed the effects of resistance and aerobic training in older men, using 20 subjects aged 65-74 years with little or no weight lifting experience. The subjects were assigned to either a resistance training and aerobic training group or

just an aerobic training group for the 18 weeks of the study. They exercised 3 times a week, with the resistance training group performing 3 sets of 4 exercises while also cycling 30 minutes during each workout. The study concluded that both groups experienced significant increases in VO_2 max and that both programs were extremely beneficial.

Olson et al. (1991) examined the cardiovascular and metabolic effects of bench stepping exercise in females. The study included 10 women who performed a 20-minute bench stepping workout using variable bench heights. The subjects were encouraged to practice the routine and then completed a maximal treadmill test to monitor HR, RPE, and VO_2 . During the bench stepping routine, the subjects either used no weights or held either 1 or 2 lb dumbbells in each hand. Those subjects who used hand weights produced greater increases in HR compared to no weights. On average, those subjects using hand weights burned 20 more calories per workout than those who used no hand weights at all.

In another study by Kraemer et al. (2001), the effect of resistance training combined with bench step aerobics was tested to examine its impact on women's health profiles. This study looked at four groups, one performing reduced time bench step aerobics (BSA), one doing longer duration BSA, another looking at the effect of BSA and resistance training, and a control group. The participants exercised 3 times a week over a 12-week period with 12 subjects included in each group. The results indicated that all three exercise groups experienced significant improvements in peak VO_2 and that HR post-exercise decreased for the short duration BSA group and the combined BSA and resistance training group. The BSA and resistance training group improved muscle performance to the greatest degree. The study concluded that resistance training can

result in improvements in aerobic fitness when combined with BSA, while also increasing muscle mass and strength. The researchers also discovered that the resistance training group had the greatest increase in VO_2 .

Collins et al. (1991) studied the HR/ VO_2 relationship between resistance training and aerobic exercise. The researchers used 15 males with previous lifting experience who first performed a maximal treadmill test to determine VO_{2max} and HRmax. The subjects were studied on two separate occasions and performed 4 different exercises at 40, 50, 60 and 70% of 1RM. They performed 3 circuits of 10 repetitions per set, with 30 seconds rest between each set. The results showed that VO_2 was highest in circuits two and three and averaged 33-47% of VO_{2max} , while HR was between 63 and 82% of maximal values. They also discovered that VO_2 was higher during leg exercises than arm exercises despite similar HR values.

Pressor Response

Porcari and Curtis (1996) described the factors related to the pressor response and how this concept can be used to explain why HR is disproportionately elevated relative to oxygen consumption during resistance training. The pressor response is a nervous reflex originating from the contraction of skeletal muscle that helps determine the HR and blood pressure (BP) responses to exercise. Three areas associated with the pressor response are the reason for the differences in the cardiovascular responses to exercise. Central command is a concept whereby the brain sends impulses to the working muscles during resistance training, while also sending an equal number of impulses to the cardiovascular center in the brain to regulate HR and BP. During high intensity resistance training, central command is much higher because a greater number of muscle fibers are being

recruited than during aerobic exercise. Intramuscular compression in the working muscle is a concept whereby the contracted muscles exert a compressive force on the blood vessels, making it difficult for fresh, oxygenated blood to reach the tissues and difficult for waste to be removed. This build up of waste products is greatest during isometric exercise and relatively less during aerobic exercise. This build up of waste products results in elevated HR and BP values as the body attempts to "flush out" these waste products and bring fresh blood to the exercising muscles. The final area associated with the pressor response is vasoconstriction of the vessels in the non-working muscle. During exercise, the body vasodilates the vessels in the working muscles, while vasoconstricting the non-working muscles at the same time in order to redirect blood to where it is needed. During resistance training, the amount of exercising muscle tends to be smaller than during aerobic activity. This results in a greater degree of vasoconstriction, which increases total peripheral resistance (TPR). The increase in TPR ultimately decreases stroke volume and BP. As the body tries to maintain cardiac output, HR rises disproportionately to relative VO_2 . Fitness specialists and exercise equipment manufacturers are trying to find a way to incorporate both resistance and aerobic exercise into one workout. However, the pressor response makes it very difficult for them to find a workout program that can successfully do both.

Lactate Conversions

Margaria, et al (1969), tested the energy utilization in intermittent exercise of supramaximal intensity. In this study, three subjects were used and had an initial blood lactate sample drawn to determine their resting lactate level. During the testing, the subjects were asked to run at 18 km/hr and 15% grade for 10 seconds at a time and given

rest periods of 10, 20, and 30 seconds each. The subjects were asked to run until exhaustion or a steady state was reached. Blood was drawn to determine lactate levels 3 and 5 minutes after completion of the run, with the higher value being used to determine lactic acid concentration in the blood. From the data collected, it was discovered that lactic acid accumulated most quickly during the first few runs in the series of runs completed during each visit. From the lactate data collected, they were able to develop a conversion from grams (g) of lactic acid produced into ml O₂. With the subject data attained, this was represented by the conversion where 44 milliliters of oxygen (ml O₂) is equivalent to 1 g of lactic acid produced.

A study by Di Prampero and Ferretti (1999) analyzed the energetics of anaerobic muscle metabolism. Their data helped to validate the conclusions made by Margaria, et al, (12) that there was in fact a method in which lactate produced can be accurately converted into oxygen consumption. They stated that lactate formation is an extremely useful and practical tool in order to estimate the entire body energy expenditure during supramaximal efforts. However, their conversion was much more applicable and easily understood. They stated that for every 1 mmol increase in blood lactate concentration, there is a 3.3 ml/kg/min increase in oxygen consumption. This number can be applied without any need for the assumption of the distribution of lactate.

Scott (2006) studied the contribution of blood lactate to the energy expenditure of weight lifting, examining both the aerobic and anaerobic contributions to energy expenditure. This study utilized 11 subjects with at least 3 months of previous weight training experience. During testing, the subjects performed 3 weight training exercises (arm curl, bench press, and leg press) at both 60 and 80% 1RM. They were randomly

assigned to perform two sets of a specific weight training exercise. Blood lactate was collected after both sets and oxygen consumption was also attained. To determine the lactate contribution of energy expenditure, they stated that every 1 mmol of blood lactate was equivalent to 3 ml/kg/min of oxygen consumption. The number attained for the anaerobic energy expenditure via blood lactate measurements was then added to the aerobic energy expenditure attained using data from the metabolic cart. They concluded that only utilizing the energy expenditure measured from oxygen consumption can underestimate actual energy expenditure. Anaerobic energy expenditure plays a significant role in total energy expenditure and must be accounted for.

Scott et al. (2009) performed a follow-up study analyzing the energy expenditure before, during, and after the bench press. This study used 8 subjects who had at least 3 months of weight training experience. They visited the laboratory 10 times, with the first measuring a 1RM bench press and the subsequent 9 times having the subjects lift 50% of their 1RM for 7, 14, and 21 repetitions. Lactate measures were taken at rest and then 2, 4, and 6 minutes post exercise. Peak blood lactate was taken as the highest blood lactate recorded. The study once again maintained that every 1 mmol of blood lactate concentration was equivalent to 3 ml/kg/min of oxygen consumption. They concluded that there were linear increases found between aerobic energy expenditure, anaerobic energy expenditure, and total energy expenditure with work for a single set of the bench press at 50% 1RM. They found that anaerobic exercise energy expenditure seems to increase to a greater degree with oxygen uptake as repetitions increase.

Related Lactate and Intermittent Exercise Studies

Brooks et al. (2005) wrote about the control of glycolysis and the lactate shuttle. Feed-forward control of glycolysis has factors that increase glucose 6-phosphate (G6P) levels and tend to stimulate glycolysis. These factors include stimulation of glycogenolysis (by epinephrine and muscle contractions) and glucose uptake. With exercise of moderate to high intensity, blood glucose levels rise due to stimulation of hepatic glucose production, which increases faster than the increase in muscle glucose uptake. In the cell-cell lactate shuttle, lactate is actively produced in working muscles. In some sites, this lactate produced can be shuttled between cells, stimulating a process in which glycogenolysis in one cell can supply a fuel for oxidation in another cell. With this, skeletal muscle becomes a major site for both lactate production and lactate removal. In this process, the lactate produced in the working muscle is consumed within the same tissue and never reaches the venous blood.

The text also discusses the size principle of motor unit recruitment. In this phenomenon, the motor units with larger cell bodies, such as the fast-fatigable and fast-fatigue-resistant motor units, will be used last and least frequently during recruitment. Fiber recruitment is typically determined by force or power needed to perform a certain movement. For example, with very heavy weights, fast motor units must be recruited.

Tabata et al. (1997) performed a study analyzing the metabolic profile of high intensity intermittent exercises. This study used nine male athletes that participated in a varsity sport. During this study, two intermittent exercise protocols were carried out. One involved having the subjects cycle at an intensity of 170% of VO_2 max for 20 seconds with a 10 second rest period. This procedure was repeated 6-7 times until the subjects reached exhaustion. The other protocol involved having the subjects cycle at an intensity

of 200% of VO_2 max for 30 seconds with a 2 minute rest period. This procedure was repeated 4-5 times until the subjects reached exhaustion. They concluded that both intermittent exercise protocols accumulated oxygen deficit and that oxygen uptake was close to maximum. One other finding is that once the subjects reached a certain lactate level, they were no longer able to exercise and had reached exhaustion. The first intermittent exercise protocol indicated that accumulated oxygen deficit equaled anaerobic capacity and stressed the anaerobic system maximally. They showed that high-intensity intermittent exercise is a very effective method to increase maximal oxygen uptake.

Ivy et al. (1980) studied muscle respiratory capacity and fiber type as determinants of the lactate threshold. Muscle biopsies were taken from the vastus lateralis of the subjects to determine respiratory capacity and fiber type. The study discovered significant positive correlations between the percent of slow-twitch fibers and absolute and relative lactate thresholds. These results suggested that a muscle's respiratory capacity is critically important in determining the work rate at which blood lactate accumulation begins. The proportion of slow-twitch fibers can play a role in determining the relative lactate threshold.

Summary

The primary finding from reviewing the literature is that weight training alone or weight training combined with various forms of aerobic exercise does not typically meet the guidelines outlined by ACSM for improving cardiorespiratory endurance. Due to the pressor response, heart rates may be elevated during those types of activities, but they are disproportionately elevated relative to VO_2 values. Thus, the metabolic overload to the

muscles is lower than during a traditional aerobic regimen. Anaerobic energy expenditure can be accurately converted from mmol of blood lactate into ml/kg/min of oxygen consumption. The values attained using this conversion are an integral tool in helping to accurately measure total energy expenditure. Proponents of the kettlebell workout claim that it provides an intense aerobic and strength training workout. To date, no studies reported in the English language have examined this concept.

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