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Original Research Article

Relative Exercise Intensity and Energy Expenditure of Battle Rope Exercise

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Abstract

Introduction: Battle rope (BR) training has become increasingly popular in recent years. Very few studies have evaluated the cardiorespiratory and metabolic responses to BR exercise. **Purpose:** The purpose of this study was to determine the relative exercise intensity and energy expenditure of a battle rope (BR) interval workout. **Methods:** Fourteen male volunteers (aged 19.6 ± 1.86 yrs) served as subjects in this study. Each subject performed a graded exercise test on a treadmill and completed a 14-minute BR workout. The exercise included in the BR workout were alternating arm waves, double arm waves, double arm power slams, in and out waves, snakes waves, inward arm circles, and outward arm circles. Each exercise was performed for 15 seconds with a 45-second rest period between exercises. HR, VO_2, and RPE were monitored throughout the BR workout. **Results:** The average HR response was 148 ± 14.9 bpm, which corresponded to 79 ± 8.4% of HRmax. The average VO_2 response was 26.9 ± 5.27 ml/kg/min, which corresponded to 51 ± 9.5% of VO_2max. The average RPE response was 14.2 ± 1.88. However, RPE rose steadily throughout the workout, reaching a peak of 16.3 ± 2.01. The average energy expenditure was 140.9 ± 24.62 total kcals (10.1 ± 1.53 kcals/min). **Conclusions:** The BR interval workout performed in the current study would be classified as vigorous intensity exercise and meets ACSM guidelines for improving cardiorespiratory endurance and body composition.

Key Words: HIIT, Interval Training, Vigorous Exercise.

Introduction

According to a survey of the top 20 worldwide fitness trends for 2018, high intensity interval training (HIIT) was number one on the list[1]. High intensity interval training is characterized by bursts of all out exercise followed by complete rest or light-moderate intensity periods[2]. Gibala and Shulgan[2] state that HIIT provides a very effective workout which can be completed in less time than moderate intensity endurance training. Additionally, HIIT has been shown to improve aerobic fitness and other health benefits to a greater extent than continuous training[2].

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Battle rope (BR) training has become increasingly popular in recent years and is typically performed using HIIT. Battle ropes come in various dimensions, but are generally 30-50 feet long and 1.5 to 2 inches in diameter. Battle ropes are anchored at a secured point (e.g. kettle bell, fence post, tree), and through multiple types of movement patterns, waves are created[3]. The exercise intensity of BR training depends on a number of factors, including the size, diameter, and length of the rope and the speed and amplitude of the wave motion[3].

Over the years a limited number of studies have evaluated the responses to BR training. A study by Fountaine and Schmidt[4] investigated the physiological response to a single session of BR training. One BR exercise was completed for 15 seconds followed by 45 seconds of rest. This sequence was repeated for a total of 10 repetitions. It was found that subjects were exercising at 86% of maximal heart rate (HRmax), which falls into the range recommended by American College of Sports Medicine (ACSM) for improving cardiorespiratory (CR) endurance[5].

A study by Brewer, Kovacs, Hogan, Felder, and Mitchell[6] compared the oxygen consumption (VO_2), heart rate (HR), and rating of perceived exertion (RPE) responses during a BR workout in a seated versus a standing position. Both BR workouts consisted 10 sets of double arm waves with each set consisting of 15 seconds of work follow by 45 seconds of rest. It was concluded that BR performed while sitting or standing are very similar in metabolic responses and can improve CR endurance.

Ratamess et al.[7] compared a BR circuit to other types of resistance training exercises. Thirteen resistance exercises were performed on separate days: seven free weight, five body weight, and a BR circuit consisting of three exercises. For the free weight protocol, subjects performed 3 sets of 10 repetitions with 75% of their 1 repetition maximum. Multiple sets and repetitions were used for the body weight exercises. For the push-up and push-up on a BOSU ball protocols, subjects performed 3 sets of 20 repetitions. For the burpee and push-up with lateral crawl protocols, subjects also performed 3 sets of 10 repetitions. For the plank and BR circuit protocols, subjects performed 3 sets of 30-second bouts. A standard 2-minute rest interval was used between all sets for each exercise. The BR protocol yielded the greatest VO_2 (38.6 ± 4.7 ml/kg/min), HR (153.5 ± 13.9 beats/min), and energy expenditure (10.3 ± 1.4 kcals/min) responses.

A separate study by Ratamess et al[8] examined the effects of varied rest intervals on the responses to BR training. Two exercise sessions were performed on different days, one with a 1-minute rest interval and one with a 2-minute rest interval. Blood lactate was taken at rest and after each BR series. Both intervals resulted

in significantly higher blood lactate than at baseline, but the 1-minute rest interval resulted in the highest blood lactate measurement. Oxygen consumption was also measured during both exercise sessions. Values were significantly higher for the exercise session that incorporated the 1-minute rest interval. It was concluded that a BR interval exercise with shorter rest intervals will have a greater effect on CR responses compared to a protocol with longer rest intervals.

The purpose of this study was to determine relative exercise intensity and energy expenditure (EE) of a BR interval exercise session in healthy, active individuals. According to the guidelines provided by ACSM[5], exercise intensity needs to be between 46-90% of VO_2max and 64-95% of HRmax in order to improve CR fitness. For EE, it is recommended that individuals expend 1,200-2,000 kcal per week (240-400 kcal per exercise session) in order to have a positive effect on body composition[9].

Methods

Participants

Fourteen male subjects between the ages of 18-23 years of age were recruited from the La Crosse, WI area. Subjects were considered apparently healthy and active (exercising at least 3 times a week for the past 6 months). All subjects had some experience with BR exercises prior to starting the protocol. Each subject completed a PAR-Q to screen for cardiovascular and orthopedic contraindications to exercise and eligible subjects provided written informed consent prior to participating in the study. The study was reviewed and approved by the University of Wisconsin – La Crosse Institutional Review Board for the Protection of Human Subjects.

Procedures

All subjects completed a maximal exercise test on the treadmill and a BR workout. The maximal exercise test on the treadmill was used to determine HRmax and VO_2max. Subjects were asked to walk or run on a motorized treadmill at a self-selected pace. The test started at a 0% grade and increase by 2.5% every 2 minutes until volitional exhaustion. Throughout the test, HR was recorded each minute using a Polar HR monitor (Polar Electro, Kempele, Finland), VO_2 was measured using an Oxycon Mobile portable metabolic system (CareFusion, Yorba Linda, CA), and RPE was recorded at the end of each 2-minute stage and at maximal exertion using the 6-20 Borg scale[10]. Prior to each test, the metabolic system was calibrated with gases of known concentrations (16.02% O_2, 4.00% CO_2) and with room air (20.93% O_2, and 0.03% CO_2) as per manufacture guidelines. Calibration of the pneumotachometer was done via a 3 Liter calibration syringe. Maximal heart rate was defined as the highest HR recorded at any point during the test and VO_2max was defined as the highest 30-second value for VO_2 during the test. Energy expenditure was calculated from the VO_2 data assuming a constant of 5 kcal for each liter of O_2

consumed. The treadmill exercise test was completed at least 48 hours in advance of the BR session.

Prior to the BR session, subjects warmed-up on a Schwinn Airdyne for 5-minutes. The BR used in this study was 50 feet long by 1.5 inches in diameter and was anchored at it's mid-point by being wrapped around a weighted sled. The workout consisted of the seven exercises listed in Table 1. Subjects practiced all of the exercises prior to being tested. For each exercise, the subject started by grasping one end of the rope in each hand with palms facing each other, feet shoulder width apart, and the knees slightly bent. Each exercise was performed twice, and the workout consisted of 15 seconds of exercise followed by 45 seconds of rest. Total workout time was 14 minutes. During the rest periods, subjects were asked to sway back and forth as a form of active recovery. Exercises were presented in a random sequence for each participant. Each subject was asked to complete the workout at a self-selected intensity, but were encouraged to exercise as fast and hard as possible. Heart rate was recorded throughout the workout with a Polar HR monitor, VO_2 was measured continuously using the Oxycon Mobile portable metabolic system, and RPE was assessed after every exercise using the 6-20 Borg Scale. Blood lactate was measured at rest and 5 minutes after the BR exercise session using a Lactate Plus Meter (Nova Biomedical, Waltham, MA). Once the BR workout was completed, subjects completed a 5-minute active recovery on the Airdyne.

Table 1. Battle Rope Exercises.

Exercises	Descriptions
Alternating arm wave (AAW)	Move both arms up and down in an alternating pattern.
Double arm wave (DAW)	Move both arms up and down in unison.
Double arm power slams (DAPS)	Bring both arms up overhead and then forcefully slam the ropes down into the ground, lowering into a deep squat when the ropes are brought down; then straighten up to return to the standing position.
In and out waves (IO)	Move both arms in toward one another and then back out, similar to a clapping motion.
Snake waves (SNA)	Move both arms side to side in unison, making the ropes look like two snakes on the floor.
Inward arm circles (IAC)	Move both arms in a circular pattern bringing the arms together or closer together at the top of the circle.
Outward arm circles (OAC)	Move both arms in a circular pattern moving both arms outward or away from each other at the top of the circle.

Statistical analyses

Standard descriptive statistics were used to characterize the subject population and to summarize the data. All values represent mean ± standard deviation. There was no significant difference in HR, VO_2, or RPE between the first and second set for each exercise, thus data for sets one and two were combined for analysis. Differences in VO_2, HR, and RPE between exercises were analyzed using a one-way ANOVA with repeated measures. Alpha level was set at $p<0.05$ to achieve statistical significance. All analyzes were conducted using the Statistical Package for the Social Sciences (SPSS, version 25; SPSS Inc., Chicago, IL).

Results

The descriptive characteristics of the subjects who participated in this study are presented in Table 2.

Heart rate responses to the seven different BR exercises are presented in Table 3. Overall, subjects exercised at an average HR of 148 ± 14.9 bpm and 79 ± 8.4% of HRmax. The average HR and %HRmax for DAPS and OAC were significantly greater than DAW and IO. The average peak HR observed for the BR exercise session was 162 ± 11.6 bpm, with an average peak %HRmax of 87 ± 6.0.

Table 2. Descriptive characteristics of subjects (N=14).

	Mean ± SD	Range
Age (years)	19.6 ± 1.86	18 – 23
Height (cm)	178.9 ± 8.20	167.6 – 190.5
Weight (kg)	78.0 ± 9.59	62.7 – 92.7
VO_2max (ml/kg/min)	52.7 ± 5.86	39.8 – 63.4
HRmax (bpm)	186.8 ± 7.64	170 – 195

Table 3. Heart rate responses to the seven Battle Rope exercises.

	HR (bpm)	Range	%HRmax	Range
IO	144 ± 13.9	113 – 167	77 ± 7.3	58 – 92
AAW	148 ± 17.8	99 – 169	79 ± 9.7	57 – 99
DAW	144 ± 14.0	89 – 169	77 ± 9.0	47 – 95
DAPS	152 ± 14.8[ab]	101 – 167	82 ± 9.3[ab]	49 – 98
SNA	146 ± 16.7	92 – 160	78 ± 9.2	55 – 98
IAC	148 ± 12.9	113 – 167	80 ± 7.4	65 – 96
OAC	151 ± 13.9[ab]	115 – 172	81 ± 7.1[ab]	63 – 94

[a]Significantly greater than IO ($p<0.05$).
[b]Significantly greater than DAW ($p<0.05$).

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Oxygen consumption responses to the seven different BR exercises are presented in Table 4. Overall, subjects exercised at an average VO_2 of 26.9 ± 5.27 ml/kg/min and 51 ± 9.5% of VO_2max. The average VO_2 and %VO_2max for DAPS was significantly greater than all other exercises. The average peak VO_2 for the BR exercise session was 32.8 ± 5.38 ml/kg/min, with an average peak %VO_2max of 63 ± 7.5.

Rating of perceived exertion responses to the seven different BR exercises are presented in Table 5. There was no significant difference in average RPE between the BR exercises. The average peak RPE for the BR exercise session was 16.3 ± 2.01.

Blood lactate measurements taken at rest and at the completion of the BR workout are presented in Figure 1. Resting and post workout blood lactates were 2.9 ± 1.36 mmol and 11.8 ± 4.24 mmol respectively.

Energy expenditure during the BR workout is presented in Table 6. Aerobic EE was calculated from the VO_2 data assuming a constant of 5 kcal per liter of O_2 consumed. Anaerobic EE was determined from the difference between post lactate and resting lactate values, multiplied by body weight, then by 3.3 mL O_2[11].

Table 4. Oxygen consumption responses to the seven Battle Rope exercises

	VO_2 (ml/kg/min)	Range	%VO_2max	Range
IO	24.1 ± 5.02	12.5 – 34.6	46 ± 8.2	29 – 63
AAW	27.2 ± 5.72	16.2 – 39.8	52 ± 9.1	31 – 72
DAW	26.8 ± 5.82	16.0 – 37.5	51 ± 10.1	35 – 70
DAPS	30.7 ± 5.25[a]	20.6 – 43.4	58 ± 9.2[a]	37 – 78
SNA	25.8 ± 5.06	13.9 – 35.5	49 ± 9.9	27 – 65
IAC	26.1 ± 3.99	16.6 – 34.8	50 ± 8.9	32 – 63
OAC	27.4 ± 6.05	17.9 – 43.8	52 ± 11.0	30 – 79

[a]Significantly greater than all other exercises.

Table 5. Rating of perceived exertion for the seven Battle Rope exercises.

	RPE	Range
IO	14.2 ± 1.91	10 – 18
AAW	14.7 ± 2.19	10 – 18
DAW	13.7 ± 1.88	9 – 19
DAPS	14.9 ± 2.07	10 – 19
SNA	13.5 ± 1.68	10 – 18
IAC	14.3 ± 1.66	10 – 18
OAC	14.6 ± 1.78	10 – 18

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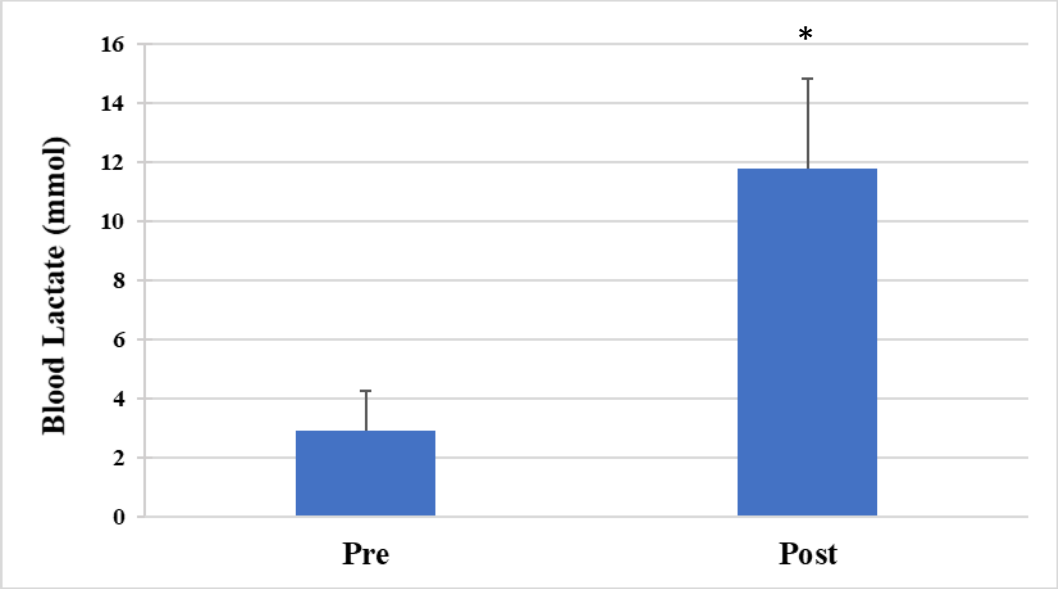

Figure 1. Blood lactate responses at rest and after the Battle Rope workout.
*Significantly different than Pre.

Table 6. Energy expenditure during the Battle Rope workout.

		Range
Aerobic kcals	130.8 ± 21.39	90.7 – 170.5
Anaerobic kcals	10.1 ± 4.63	3.5 – 17.1
Total kcals	140.9 ± 24.62	100.7 – 180.5
Kcal/min	10.1 ± 1.53	7.2 – 12.9

The HR response of a single subject during the BR workout is presented in Figure 2. Because each subject completed the BR exercises in a different order, a composite graph could not be generated. The boxed region represents the current ACSM guidelines for improving cardiorespiratory endurance for this participant based on his individual HRmax[5]. The dotted line represents the delineation between moderate intensity (64%-76% of HRmax) and vigorous intensity (77%-95% of HRmax). As can be seen, there was a tendency for HR to drift upwards over the course of the BR workout.

The VO_2 response during the BR workout of the same subject represented in Figure 2 is presented in Figure 3. The boxed region represents the current ACSM guidelines for improving cardiorespiratory endurance for this participant based on %VO_2max[5]. The dotted line represents the delineation between moderate intensity (46%-63% of VO_2max) and vigorous intensity (64%-90% of VO_2max).

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The RPE response of the same subject during the BR workout is presented in Figure 4. The boxed region represents the current ACSM guidelines for improving cardiorespiratory endurance for this participant based on RPE[5]. The dotted line represents the delineation between moderate intensity (12-13 RPE) and vigorous intensity (14-17 RPE). It can be seen that the RPE drifted upwards continuously over the course of the BR workout.

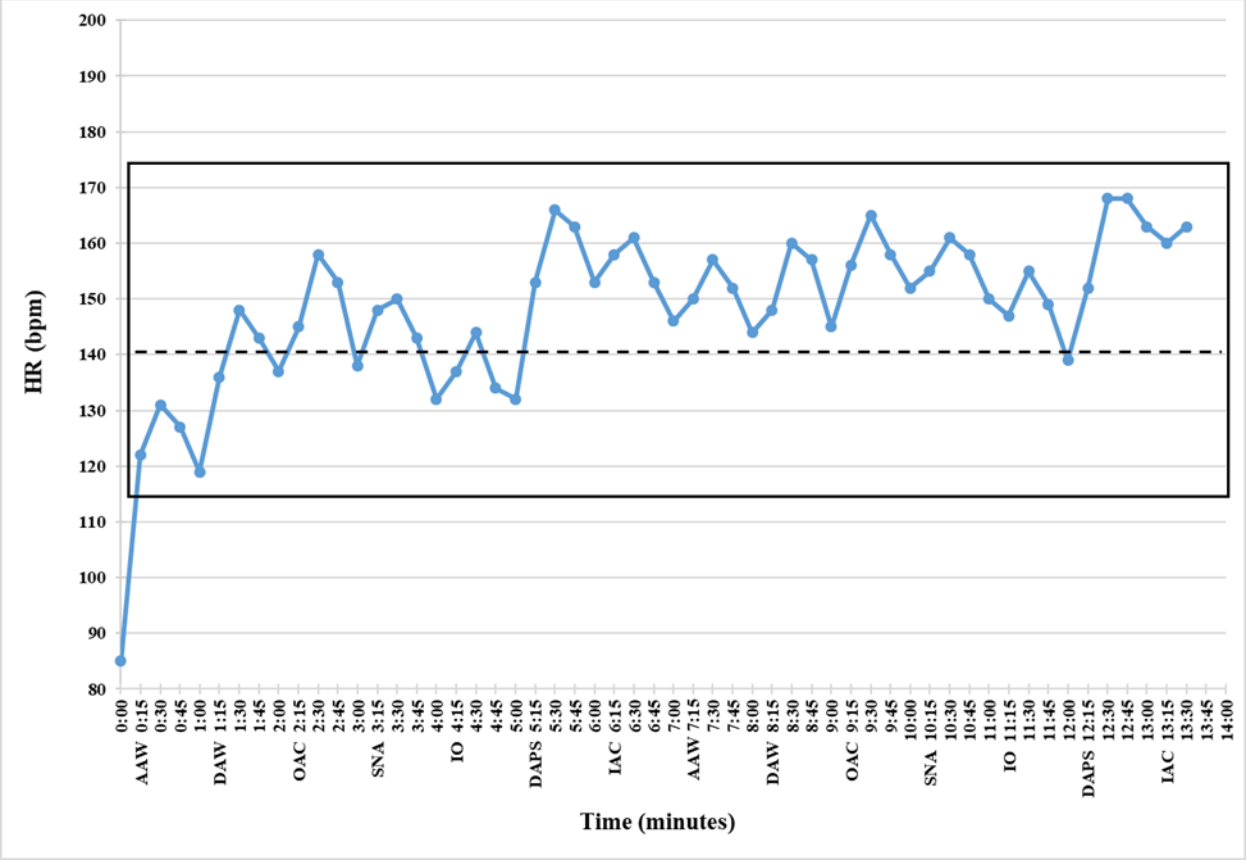

Figure 2. Heart rate response of a single participant during the Battle Rope workout.

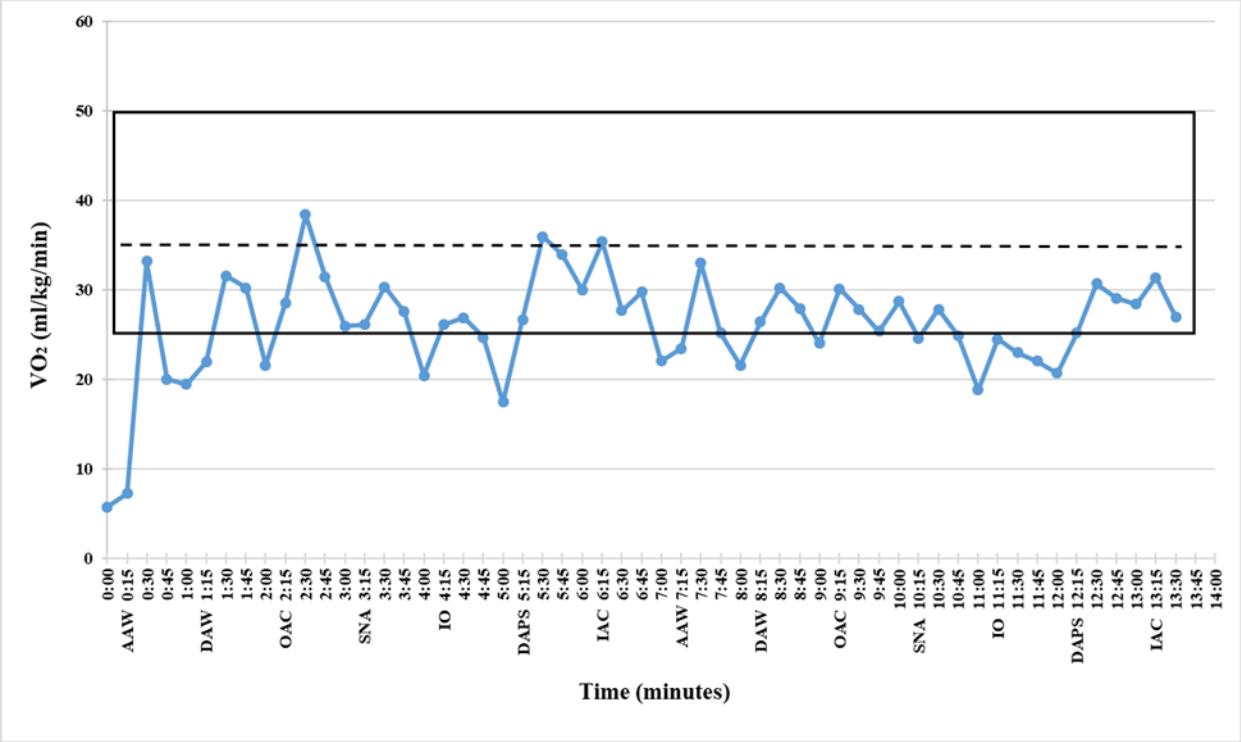

Figure 3. Oxygen consumption response of a single participant during the Battle Rope workout.

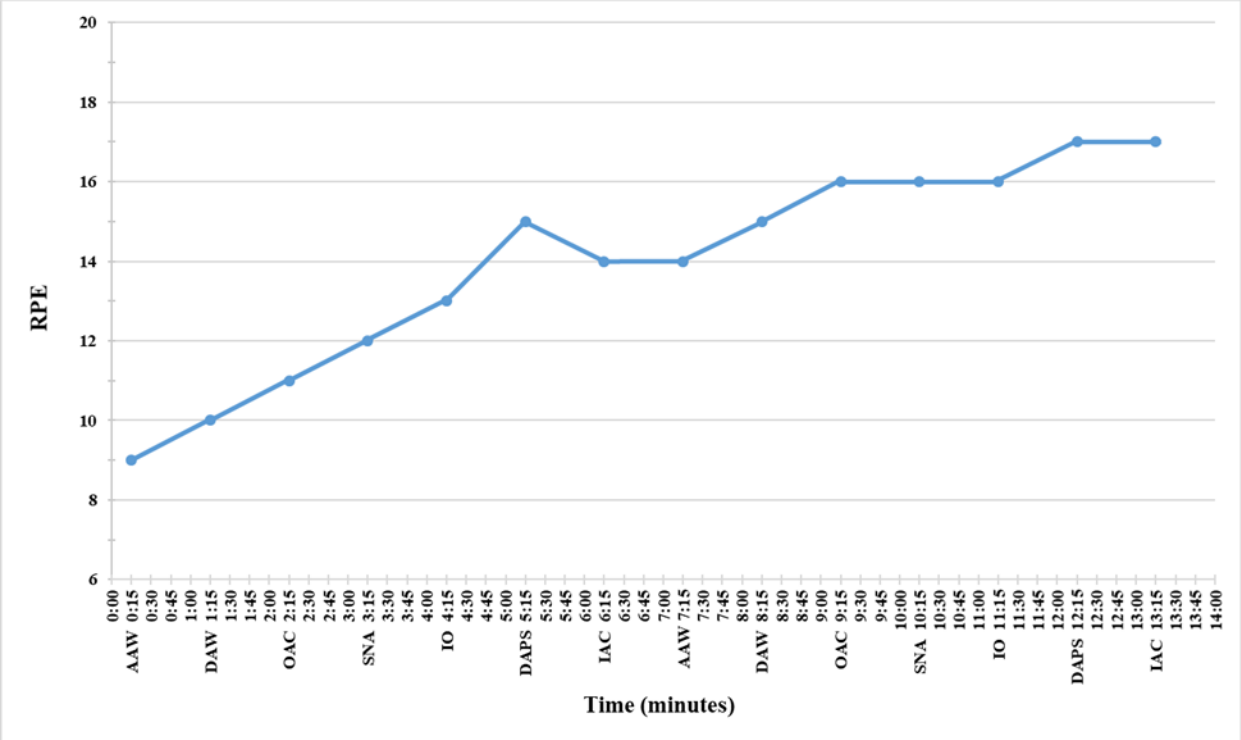

Figure 4. Rating of perceived exertion response of a single participant during the Battle Rope workout.

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Discussion

The purpose of this study was to determine the relative exercise intensity and EE during a BR interval exercise session in healthy, active individuals. ACSM recommends that individuals accumulate 30 minutes of moderate intensity exercise 5 days a week or 20 minutes of vigorous intensity exercise 3 days a week in order to improve cardiorespiratory fitness[5]. Moderate intensity exercise is defined as a HR between 64% and 76% of HRmax, a VO_2 between 46% and 63% of VO_2max, or RPE of 12-13. Vigorous intensity exercise is defined as a HR between 77% and 95% of HRmax, a VO_2 between 64% and 90% of VO_2max or RPE of 14-17.

Overall, it was found that subjects worked at an average HR of 148 ± 14.9 bpm and 79% of HRmax during the BR workout, which falls into the vigorous intensity range. The BR exercise with the highest average HR response was DAPS (152 ± 14.8 bpm), and the BR exercises with the lowest HR responses were IO (144 ± 13.9 bpm) and DAW (144 ± 14.0 bpm), respectively. Fountaine and Schmidt[4] and Brewer et al.[6] both performed studies on BR training and utilized identical work and rest intervals as the current study; 15 seconds of work interspersed with 45 second rest periods. However, those studies only compared the responses during DAW, whereas the current study compared the HR responses of seven different BR exercises. Fountaine and Schmidt[4] found that during DAW, subjects had an average HR of 158 ± 14 bpm. Similarly, subjects in the study by Brewer et al.[6] had an average HR of 157 ± 14.1 bpm during DAW. This study found that subjects had an average HR of 144 ± 14.0 bpm during DAW which was slightly lower than the two previous studies. Peak HR response for the BR workout was 162 ± 11.6 bpm, which was 9 beats lower than the results of both Fountaine and Schmidt[4] 171 ±11 bpm and Brewer et al.[6] 171 ± 13.8 bpm. In the current study, average relative intensity of the workout was 79 ± 8.4% of HRmax, which again is somewhat lower than the results of Fountaine and Schmidt[4] (86% of HRmax) and Brewer et al.[6] (85% of HRmax). However, during all of the exercises in the current study, subjects were working at an average %HRmax of 77% which is classified as vigorous intensity exercise according to ACSM guidelines[5].

Overall, subjects exercised at an average VO_2 of 26.9 ± 5.27 ml/kg/min and 51 ± 9.5% of VO_2max. The BR exercise with the highest average VO_2 response was DAPS (30.7 ± 5.25 ml/kg/min) and the BR exercise with the lowest average VO_2 response was IO (24.1 ± 5.02 ml/kg/min). In the study by Brewer et al.[6], subjects exercised at an average VO_2 of 21.2 ± 5.95 ml/kg/min, which is lower compared to all of the exercises in the current study, including DAW, which was the only exercise used in their study. Ratamess et al.[7] also measured VO_2 during their study on BR training, and recorded an average VO_2 of 24.6 ± 2.6 ml/kg/min, which is similar to the current study. Peak VO_2 varied considerably between studies. In the current study, peak VO_2 was 32.8 ± 5.38 ml/kg/min. Brewer et al.[6] found a peak VO_2 of 26.6 ± 6.18 ml/kg/min and Fountaine and Schmidt[4] recorded a peak VO_2 of 40.2 ± 3.0 ml/kg/min. When comparing relative exercise intensity between studies, the %VO_2max was very similar,

ranging from 50-52%VO_2max[6,7]. However, in the current study, during DAPS subjects were working at an average of 58% of VO_2max. Thus, if individuals want a more vigorous BR workout, they may want to include DAPS.

When looking at the relative exercise intensity data, exercising at 50-52% of VO_2max falls into the moderate intensity range based on ACSM guidelines[5]. However, another way to classify exercise intensity is using METs. According to the guidelines provided by ACSM[5], moderate intensity exercise is defined as 3.0-5.9 METs, and vigorous intensity exercise is defined as $\geq$ 6.0 METs. In the current study, subjects were exercising at an average VO_2 of 26.9 ml/kg/min, which corresponds to 7.7 METs. This falls into the vigorous category. The low relative intensity is due to the fact that subjects in the current study were relatively highly fit (average VO_2max of 52.7 ± 5.86 ml/kg/min) based on comparative norms[5].

Peak RPE for the BR workout was 16.3 ± 2.01. Brewer et al.[6] found a peak RPE response of 17.3 ± 2.8, which is similar to the current study. When looking at the ranges of RPE for each exercise, it can be seen that some of the RPE values were as low as 9 on the 6-20 Borg scale. Because there exercise were presented in a random order, if an exercise was performed first in the workout, it was rated as "fairly light" exercise. As can be seen in Figure 3, RPE rose steadily over the course of the workout. This is identical to what was found by Ratamess et al.[8]. Although they used the Borg category-ratio scale, they also demonstrated a progressive rise in RPE with each set of BR exercises. All the exercises in the current study elicited an average RPE greater than 13, with an average of 14.2 ± 1.88, which is classified as a vigorous intensity exercise according to ACSM guidelines[5].

Blood lactate values at the end of the BR workout were 11.8 ± 4.24 mmol. This is virtually identical to what was found by Fountaine and Schmidt[4] (11.9 mmol), who also used a 15/45 second work-to-rest ratios. Ratamess et al.[8] recorded post-exercise lactate values of ~13 mmol. However, they utilized 30-second work bouts interspersed with 1-minute rest periods. They also demonstrated lower blood lactate values (~11.7 mmol) when the rest periods were extended to 2 minutes. The main significance of the high post-exercise blood lactate values is that it indicates subjects were working at a vigorous anaerobic intensity.

For EE, it is recommended that individuals expend 1,200-2,000 kcal per week (240-400 kcal per exercise session) in order to have a positive effect on body composition[9]. The average EE in the current study was 10.1 ± 1.53 kcals/min. Once again, this is similar to the results of Fountaine and Schmidt[4], who found an average EE of 9.9 ± 3.4 kcals/min. These results are also similar to the findings of Ratamass et al.[8] (10.3 ± 1.4 kcals/min), despite the fact that subjects in their study performed 30-second work bouts. The total number of kcals burned during the BR workout was 140.9 ± 24.62, which is below the recommended guidelines for positively affecting body composition. However, this was solely due to the short nature of the workout (14 minutes).

There were several limitations of the current study. We evaluated the responses to seven BR exercise. There are many other exercises that can be included in a BR workout. While we encouraged subjects to exercise as hard and as fast as possible, we did not record the number of oscillations during each interval. Additionally, we utilized 15-second work intervals. Other studies have sometimes utilized longer work intervals (30-60 seconds). There are also differences in the length and thickness of the BR that can be used. Since the BR is a fixed length and weight for all subjects, it provides a relatively different challenge for subjects of different sizes and strengths. Another limitation was that all of the subjects were young, active males. Responses in females, older, or more sedentary individuals could results in different responses. Thus, further research should be conducted in other populations to evaluate the CR responses and relative exercise intensity of different BR exercise sessions.

Conclusions

In summary, we found that a BR exercise session meets ACSM guidelines[5] for improving CR endurance and would be classified a vigorous intensity activity. Based on the HR and VO_2 responses, DAPS were the most intense exercise. A BR is a very versatile training aid and provides a versatile option for someone trying to improve CR endurance.

Disclosures

This study was funded by the American Council on Exercise (ACE). However, ACE was not involved in the design of this study, collection or analysis of the data, or the preparation of this manuscript.

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References

1. Thompson WR. (2017). Worldwide survey of fitness trends for 2018. *ACSMs Health Fit J*, 21, 10-19.
2. Gibala M, & Shulgan C. (2017). *The One Minute Workout: Science Shows a Way to Get Fit That's Smarter, Faster, Shorter*. New York, NY: Avery.
3. Stanforth D, Brumitt J, Ratamess N, Atkins W, Keteyian S. (2015). Training toys…bells, ropes, and balls-oh my! *ACSMs Health Fit J*, 19, 5-11.
4. Fountaine CJ, & Schmidt BJ. (2015). Metabolic cost of rope training. *J Strength Cond Res*, 29, 889-893.
5. Riebe D. (2018). *ACSM's Guidelines for Exercise Testing and Prescription* (10th ed). Philadelphia, PA: Wolters Kluwer Health.
6. Brewer W, Kovacs R, Hogan K, Felder D, Mitchell H. (2018). Metabolic responses to a battle rope protocol performed in the seated or standing positions. *J Strength Cond Res*, 32, 3319-3325.
7. Ratamess NA, Rosenberg JG, Klei S, Dougherty BM, Kang J, Smith CR, Ross RE, Faigenbaum AD. (2015). Comparison of the acute metabolic responses to traditional resistance, body-weight, and battling rope exercises. *J Strength Cond Res*, 29, 47-57.
8. Ratamess NA, Smith CR, Beller NA, Kang J, Faigenbaum AD, Bush JA. (2015*).* Effects of rest interval length on acute battling rope exercise metabolism. *J Strength Cond Res*, 29, 2375-2387.
9. Donnelly, J., Blair, S., Jakicic, J., Manore, M., Rankin, J., & Smith, B. (2009). Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Med Sci Sports Exerc*, 41, 459-471.
10. Borg G. (1982). *Psychophysical bases of perceived exertion*. *Med Sci Sports Exerc*, 14, 377-381.
11. di Prampero PE, & Ferretti G. (1999). The energetics of anaerobic muscle metabolism: A reappraisal of older and recent concepts. *Respir Physiol*, 118, 103-115.