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Acute Physiological Responses to Rope Climbing Ergometer High-Intensity Interval Training in Males and Females

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Abstract

International Journal of Exercise Science 18(3): 1355-1366, 2025. https://doi.org/10.70252/EAFV3707 This study aimed to assess the acute physiological responses to a single bout of rope climbing high-intensity interval training (RC-HIIT) and compare the responses between sexes as no data currently exists on this training modality. Following an overnight fast, body composition was assessed, and resting measurements were recorded. Participants then completed an exercise protocol consisting of 10 rounds of maximal effort rope climbing using a 30:60 second work:rest ratio. Gas analysis and heart rate (HR) were recorded continuously. Blood lactate (BLa) was measured following the final work interval. Participants remained seated for 25 minutes post-exercise to assess $\dot{V}O_2$ recovery. 22 recreationally active participants (11M/11F, 24 ± 7 yrs, 171.5 ± 7.9 cm, 69.9 ± 12.1 kg, 18.9 ± 6.0% body fat) completed the study. Combined average HR during exercise was 141 ± 19 bpm (74.0 ± 10.4% age predicted maximal HR (APMHR)) and peak HR reached 172 ± 17 bpm (90.3 ± 8.8% APMHR). Average exercise $\dot{V}O_2$ was 18.8 ml/kg/min with peak $\dot{V}O_2$ values of 27.2 ml/kg/min. Energy expenditure during exercise was 99 ± 28 kcal. Post-exercise BLa was 9.8 ± 3.1 mmol. PACES scores indicated high enjoyment with this modality (101.5 ± 15.9). Average exercise $\dot{V}O_2$, peak VO2, energy expenditure, and post-exercise BLa were greater in males than females ($p < 0.05$). No sex differences were observed for HR responses or exercise enjoyment. A 15-minute RC-HIIT bout induces HR responses indicative of moderate- to vigorous-intensity exercise in both sexes with greater physiological responses in males compared to females.

Keywords: HIIT, metabolism, metabolic cost, female physiology, energy expenditure

Introduction

An abundance of data has shown the effectiveness of exercise for improving body composition, health, and fitness.[1] The American College of Sports Medicine recommends that adults perform at least 75 minutes of vigorous-intensity exercise or 150 minutes of moderate-intensity exercise each week along with two days per week of resistance training.[2,3] Despite the known benefits of exercise, only 24.2% of U.S. adults meet these recommendations.[4] Lack of time has been

repeatedly reported as the greatest barrier to consistent exercise participation which has led health and fitness professionals to seek more time efficient exercise modalities.[5,6]

High-intensity interval training (HIIT), characterized by bursts of vigorous exercise interspersed with low-intensity recovery or rest periods, has been shown to induce similar or greater physiological adaptations than moderate-intensity continuous training (MICT).[7,8] Additionally, HIIT is a more time efficient training modality which may increase exercise enjoyment,[9,10] resulting in improved long term adherence. However, most of the research on HIIT has investigated cycling or running protocols. Running HIIT has shown efficacy for improving health and performance [11] but is a high impact modality of training, placing greater stress on the joints and therefore may not be ideal for all populations. While cycling is a low impact training modality, cycling induces less fat loss compared to running.[11] Thus, identifying alternative low impact HIIT modalities could be beneficial for improving both cardiometabolic health and physical fitness in various populations.

Battle ropes are commonly utilized in HIIT workouts and have been shown to improve various aspects of fitness.[12,13] Fountaine and Schmidt examined the physiological responses to a single bout of battle rope HIIT consisting of 10 rounds of battle rope undulation with a 15:45 second work:rest ratio.[14] Average heart rate (HR) during exercise was 86% of age predicted maximum, suggesting that battle rope HIIT is a vigorous exercise modality with the potential to elicit positive physiological adaptations with long term use. Indeed, a later study observed increased aerobic capacity, shoulder maximal voluntary contraction, muscular power, and sit-up and push-up endurance following 10 sets of 30 second battle rope undulations with 60 second rest intervals performed thrice weekly for 3-weeks in recreationally active males and females.[12]

Traditional climbing exercise, such as indoor and outdoor rock climbing, have also been shown to elicit robust physiological responses [15,16] and positively affect health and fitness [17,18]. However, lack of skill, safety concerns, or limited accessibility may impede many from engaging in this exercise modality. Rope climbing is an alternative form of climbing exercise commonly used by tactical athletes, CrossFit® athletes, and gymnasts as part of their training programs which may also enhance health and performance. Nevertheless, little data exists on this modality, and rope climbing still presents obstacles such as a high skill component and safety concerns, which may inhibit participation.

The recent advent of rope climbing ergometers has made rope climbing training more accessible to the general population. It also represents a safe method of engaging in climbing exercise and requires less skill than traditional climbing. However, to our knowledge, no data currently exists on this exercise modality. More specifically, no data exists documenting the acute physiological responses to stationary rope climbing ergometers. As such, the aim of the present study was to quantify the physiological effects of a single bout of rope climbing ergometry HIIT (RC-HIIT) and compare the responses between males and females. Additionally, we aimed to assess the enjoyment of rope climbing ergometry as a training modality. We hypothesized that RC-HIIT would elicit HR responses indicative of vigorous-intensity exercise according to the American College of Sports Medicine criteria for cardiorespiratory fitness and that males would have

greater exercise $\dot{V}O_2$, respiratory exchange ratio (RER), energy expenditure (EE), and blood lactate (BLa) compared to females.

Methods

Participants

Using an α level of 0.05 and β of 0.8, it was estimated that 11 participants per group would be sufficient to detect large differences (ES: d = 1.25; G*Power 3.1, Germany) based on previous literature comparing physiological responses to rope training HIIT between sexes.[14,19] Healthy, recreationally active males (n = 11) and females (n = 11) participated in this study (24 ± 7 years, 171.5 ± 7.9 cm, 69.9 ± 12.1 kg, 18.9 ± 6.0 % body fat). Participant characteristics can be found in Table 1. Recreationally active was defined as performing structured physical activity two or more days per week for the previous 3 months. Participants were excluded if they were pregnant, currently using rope climbing ergometry as an exercise modality, or had any chronic disease, condition, or injury that may contraindicate participation in high-intensity exercise. No participants reported prior rope climbing ergometer use. After having the study explained to them, participants provided written and oral informed consent. After consent was given, participants completed a Physical Activity Readiness Questionnaire (PAR-Q) to ensure their ability to perform high-intensity exercise. This study was approved by the Institutional Review Board (PRO0136450) and was carried out in accordance with the Declaration of Helsinki and the ethical standards of the *International Journal of Exercise Science*.[20]

Table 1. Participant Characteristics

Characteristic	Total *(N = 22)*	Male *(n = 11)*	Female *(n = 11)*	p-value	Cohen's *d*
Age (yrs)	24 ± 7	23 ± 4	26 ± 8	0.699#	0.475
Height (cm)	171.5 ± 7.9	177.3 ± 5.3	165.7 ± 5.2**	< 0.001	2.215
Weight (kg)	69.9 ± 12.1	77.3 ± 11.7	62.5 ± 6.9**	0.002	1.538
Body Fat %	18.9 ± 6.0	15.2 ± 3.8	22.6 ± 5.6**	0.002	1.290
FFM (kg)	56.8 ± 11.4	65.3 ± 8.6	48.3 ± 6.1**	< 0.001#	2.259
FM (kg)	13.1 ± 4.2	12.0 ± 4.2	14.2 ± 4.1	0.229	0.370
Resting HR (bpm)	66 ± 14	68 ± 14	64 ± 13	0.426	0.347
Resting $\dot{V}O_2$ (mL/kg/min)	3.4 ± 0.4	3.5 ± 0.5	3.4 ± 0.4	0.332#	0.150
Resting RER	0.83 ± 0.06	0.83 ± 0.09	0.83 ± 0.03	0.116#	0.032
Resting lactate (mmol)	1.03 ± 0.40	1.06 ± 0.47	1.00 ± 0.34	0.760	0.132

Data are presented as mean ± SD. FFM = fat-free mass; FM = fat mass; bpm = beats per minute; RER = respiratory exchange ratio;** Indicates significant sex differences ($p < 0.01$). # indicates non-parametric independent samples t-test.

Protocol

Participants were asked to arrive in the morning following an overnight fast and abstaining from caffeine (12h) and alcohol and strenuous exercise (24h). Pretesting procedures were verbally confirmed with participants. After being given the chance to void their bladder and bowel, participants were asked to remove their shoes and socks and wear compression athletic clothing. Height was then recorded (InBody BSM 270B, USA). Next, body composition was

assessed via multi-frequency bioelectrical impedance analysis (InBody 770, USA) and Air Displacement Plethysmography (Bod Pod, Cosmed, USA). Participants were asked to stand on the Inbody, legs separated and not touching, grasping the handles with arms approximately 30° from the body. Body weight was recorded from a calibrated scale (Bod Pod, Cosmed, USA). Body density from Air Displacement Plethysmography and total body water from bioelectrical impedance analysis were utilized in a 3-compartment model [21] to determine body composition using:

$$BF\ \% = \left(\frac{211.5}{Body\ Density}\right) - 78.0\left(\frac{TBW}{Body\ Mass}\right) - 134.8$$

Following body composition testing, participants were fitted with a HR monitor (Polar H10) and mask. Resting HR, RER, and $\dot{V}O_2$ were recorded and averaged during a 5-minute seated rest. BLa via fingerstick (Lactate Plus, Novabiomedical, USA) was measured following the 5-minute seated rest period. After resting measurements were recorded, participants completed a standardized warm-up consisting of 3-minutes of treadmill walking at 3.0 mph followed by two 30 second rounds of submaximal rope climbing with the same resistance as the exercise protocol to acclimate participants to the equipment.

Participants then performed the exercise protocol which consisted of 10 rounds of 30 seconds of maximal effort rope climbing interspersed with 60 seconds of rest on a stationary rope climbing ergometer (ER330, Axios, USA; See Figure 1A-B). This protocol was selected based on previous work demonstrating a similar protocol using battle ropes elicited robust physiological responses in college-aged males and females.[19] Resistance on the rope climbing ergometer is controlled with a dial and was set to one turn for females and 1.5 turns for males. The resistance was chosen based on pilot testing suggesting the selected resistance elicited an average HR response ≥ 76% age predicted maximum heart rate (APMHR) throughout the protocol. Each set alternated between single and double arm climbs to prevent local fatigue. During each rest interval, participants were asked to assume a seated position and minimize movement. HR, RER, and $\dot{V}O_2$ were recorded continuously throughout the exercise protocol. Rate of perceived exertion (RPE) using a 6-20 Borg scale, as well as distance and hand speed provided by the ergometer, were recorded immediately following each work interval. BLa was recorded 2 minutes after completion of the exercise protocol. Immediately following the exercise protocol, participants were asked to remain in a seated position for 25 minutes to assess $\dot{V}O_2$ recovery. Lastly, participants completed the Physical Activity Enjoyment Scale (PACES) to quantify enjoyment of RC-HIIT as a training modality.[22]

Resting VO_2, exercise VO_2, recovery VO_2, EE, and RER were measured via indirect calorimetry (ParvoMedics TrueOne® 2400 Metabolic Cart, USA) in 15-second sampling periods. As data processing strategies alter $\dot{V}O_2$ responses,[23] this method was selected to match the most closely aligned study available in the literature[14] and to improve direct comparisons of metabolic responses. The metabolic cart was calibrated according to manufacturer specifications prior to each trial. The equation proposed by Tanaka et al (208 – 0.7 x age) was used to calculate APMHR.[24] All BLa samples were taken in duplicate and averaged for final analyses. Data

collection occurred in a temperature-controlled laboratory (23.7 ± 1.0 °C) between May and July 2024.

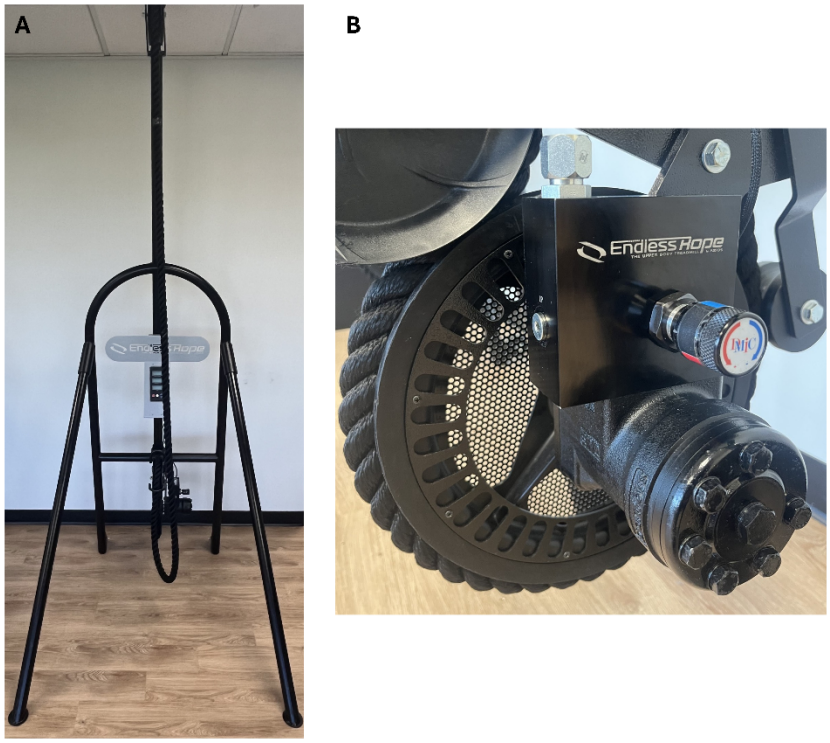

Figure 1. Rope climbing ergometer (A) and ergometer resistance dial (B)

Statistical Analysis

Data was analyzed using SPSS (version 29) Statistics software package (IBM). Participant characteristics and combined physiological responses are presented using descriptive statistics. Two tailed independent samples t-tests were used to detect differences between males and females. A 2 x 2 repeated measures ANOVA was utilized to detect differences in blood lactate concentrations. Normality was assessed using Shapiro-Wilk tests. If normality was violated, non-parametric independent sample t-tests were utilized. Outcome measures with outliers were analyzed with and without outliers included. As the interpretation of findings did not change, outliers were included in final analyses. To better interpret comparisons, Cohen's d effect sizes were utilized. Effects were defined as small ($0.2 < d < 0.5$), medium ($0.5 < d < 0.8$), and large ($d \geq 0.8$). Significance was set at $p < 0.05$ with a trend considered $0.05 \leq p < 0.10$. Data are presented as mean ± standard deviation.

Results

Participants

Sex differences were observed where males had greater height ($p < 0.001$), weight ($p = 0.002$), and fat-free mass (FFM) ($p < 0.001$) while females had a higher body fat percentage ($p = 0.002$).

No differences were observed for fat mass, resting HR, resting $\dot{V}O_2$, resting BLa, or RER between sexes.

Table 2. Physiological Responses to Rope Climbing Ergometer HIIT

Variable	Total (*n* = 22)	Male (*n* = 11)	Female (*n* = 11)	p-value	Cohen's *d*
Avg Exercise HR (bpm)	141 ± 19	146 ± 20	137 ± 19	0.171#	0.480
Peak Exercise HR (bpm)	172 ± 17	174 ± 16	171 ± 17	0.652#	0.188
Avg Exercise HR (% APMHR)	74.0 ± 10.4	75.9 ± 10.0	72.1 ± 10.9	0.411	0.358
Peak Exercise HR (% APMHR)	90.3 ± 8.8	90.6 ± 8.5	90.0 ± 9.5	1.000#	0.060
Avg Exercise VO_2 (ml/kg/min)	18.8 ± 3.2	20.3 ± 3.2	17.3 ± 2.4*	0.024	1.040
Peak Exercise VO_2 (ml/kg/min)	27.2 ± 4.8	29.4 ± 5.1	25.0 ± 3.3*	0.026	1.028
Post-exercise Lactate (mmol)	9.8 ± 3.1	11.7 ± 2.8	7.9 ± 2.0**	0.001	1.618
Avg Exercise RER	1.08 ± 0.05	1.10 ± 0.03	1.06 ± 0.06†	0.05	0.889
RPE	14 ± 2	15 ± 1	14 ± 2	0.108	0.717
Average Distance (m)	42 ± 5	40 ± 5	45 ± 5*	0.041	0.930
Average Hand Speed (m/s)	82 ± 9	78 ± 8	87 ± 9*	0.023	1.049
EEE (kcal)	99 ± 28	117 ± 24	81 ± 18**	0.001	1.702
Recovery EE (kcal)	47 ± 13	56 ± 13	39 ± 7**	0.001	1.622
25-min Recovery VO_2 (ml/kg/min)	5.42 ± 0.84	5.74 ± 0.96	5.06 ± 0.52	0.064	0.720

Data are presented as mean ± SD. HR = heart rate; bpm = beats per minute; APMHR = age predicted maximum heart rate; RER = respiratory exchange ratio; EEE = energy expenditure during exercise; RPE = rating of perceived exertion; * Indicates significant sex differences ($p < 0.05$); ** Indicates significant sex differences ($p < 0.01$); † Indicates trend for significant sex differences ($p = 0.05$). # indicates non-parametric independent samples t-test.

Physiological Variables

During the working portion of the HIIT bout, participants covered 42 ± 5 m with a hand speed of 82 ± 9 m/s. Rope climbing HIIT increased HR, with the average during the entire bout (work and rest) at 74.0 ± 10.4% APMHR and peak values of 90.3 ± 8.8% APMHR. Similarly, $\dot{V}O_2$ increased during exercise, with the average during the entire bout (work and rest) at 18.8 ± 3.2 ml/kg/min and peak values of 27.2 ± 4.8 ml/kg/min. Average RER during exercise was 1.08 ± 0.05. For lactate concentrations, there was a significant time effect ($p < 0.001$) such that BLa significantly increased two minutes post-exercise compared to resting concentrations (9.8 ± 3.1 vs 1.03 ± 0.4 mmol, respectively). RPE, averaged across all 10 rounds, was 14 ± 2. EE during exercise (EEE) was 99 ± 28 kcal. Refer to Table 2 for physiological variables.

Sex Differences in Physiological Variables

Average $\dot{V}O_2$ ($p = 0.024$), peak $\dot{V}O_2$ ($p = 0.026$), and EEE ($p < 0.001$), were greater in males compared to females during exercise. Similarly, there was a significant interaction for BLa concentrations ($p = 0.001$) such that males had a greater increase post-exercise compared to females. A trend toward higher RER in males ($p = 0.05$) was observed. Females covered greater distance ($p = 0.041$) and had greater hand speed ($p = 0.023$) during exercise. No differences were observed between the sexes for HR response or RPE during exercise. Refer to Table 2 for physiological variables by sex.

Recovery and Enjoyment

After completion of exercise, one participant declined to participate in the recovery gas analysis. Accordingly, recovery data are presented for 21 participants (10M/11F). Recovery EE was 47 ± 13 kcal, with males expending greater energy compared to females (56 ± 13 vs. 39 ± 7 kcal, respectively; $p < 0.01$). Average 25-min recovery $\dot{V}O_2$ was 5.42 ± 0.84 ml/kg/min, with no significant differences between males and females ($p = 0.064$). Three male participants (30%) and eight female participants (73%) returned to their resting $\dot{V}O_2$ during the 25-min recovery period (defined as two consecutive $\dot{V}O_2$ values within 5% of resting $\dot{V}O_2$ [ml/kg/min]). An exploratory Chi-Square Test of Association was conducted to determine if a greater proportion of females reached resting values than males, which trended toward significance ($p = 0.050$). PACES scores following exercise were 101.5 ± 15.9, with no differences between males and females (101.3 ± 14.7 vs. 101.8 ± 17.8, respectively).

Discussion

HIIT is a time efficient and effective strategy for improving health and fitness.[12] However, no data currently exists on the use of rope climbing ergometers as a modality for HIIT. In this study, we demonstrate the acute physiological responses to a 15-minute bout of RC-HIIT using 10 rounds of 30 second "all out" effort interspersed with 60 seconds of rest in males and females. We hypothesized that RC-HIIT would elicit HR responses indicative of vigorous exercise according to the American College of Sports Medicine criteria for cardiorespiratory fitness and that males would have greater exercise $\dot{V}O_2$, RER, EE, and BLa compared to females. Our hypotheses were partially met, and our results suggest that in recreationally active males and females, RC-HIIT is a moderate- to vigorous-intensity mode of exercise and that males have a greater exercise $\dot{V}O_2$, RER, EE, and BLa in response to this modality of training.

As a percentage of APMHR, rope climbing ergometer training elicited average and peak HR of 74.0 ± 10.4% and 90.3 ± 8.8%, respectively. Twelve of 22 participants (7M/5F) achieved an average of ≥ 76% APMHR, indicative of vigorous exercise. As no other studies with this modality of training are available, direct comparisons are not possible. However, a similar study utilizing 10 rounds of battle rope training with 15:45 sec work:rest ratios reported an average HR response of 86% APMHR in active males and females.[14] Using the same 30:60 sec work:rest ratio as the present study, Ratamess et el. reported an average HR of 164 bpm (82% APMHR) and 156 bpm (78% APMHR) for males and females, respectively during 8 rounds of battle rope exercise.[19] Although participants in the current study were instructed to exert maximal effort during all working rounds, it is possible that some participants did not. It should also be noted that a standard resistance was utilized in the present study for males and females. Consequently, it is possible that a greater resistance is required on rope climbing ergometer training to elicit similar responses to battle rope exercise. Indeed, individualized resistance settings may be required to optimize the exercise response. We observed no differences for HR response between males and females. Consistent with our findings, other studies examining HR responses with acute bouts of upper-body HIIT have also shown no significant differences between the sexes.[25]

Average and peak $\dot{V}O_2$ during the present study were 18.8 ± 3.2 and 27.2 ± 4.8 ml/kg/min, respectively. These results are similar to other rope training protocols where average and peak

VO_2 during 10 rounds of double arm swings using 15: 45 sec work:rest ratios in young, healthy males and females were 21.22 ± 5.95 and 26.56 ± 6.18 ml/kg/min, respectively.[26] Though, the battle rope protocol utilized a 100-bpm cadence as opposed to the all-out nature of the present study. It is also interesting to note that previous work has observed differences in muscle activation patterns between single and double arm battle rope exercise,[27] yet our alternating single and double arm protocol elicited similar responses to double arm only battle rope training. As no data currently exists on the motor unit recruitment and muscle activation during rope climbing ergometer use, this represents a necessary area of future investigation.

In contrast, other studies have observed greater VO_2 responses to battle rope training.[14,19,25] Peak VO_2 during 10 rounds of battle rope HIIT, with a 16.33 kg rope and 15 second rounds of maximal effort double arm waves interspersed with 45 seconds rest, was 35.4 ± 5.4 ml/kg/min in a mixed sample of active males and females.[14] Discrepant results may be attributed to the exercise modalities used, the double arm only protocol, or differences in study populations as 73% of these participants were former collegiate athletes while the present study recruited recreationally active individuals. During 3 rounds of 30 seconds maximal effort battle rope training interspersed with 2 minutes of rest, average and peak VO_2 was 24.6 ± 2.6 and 38.6 ± 4.7 ml/kg/min, respectively in resistance trained men who were current or former athletes.[25] These VO_2 responses are greater than the average (20.3 ± 3.2 ml/kg/min) and peak (29.4 ± 5.1 ml/kg/min) responses observed in males in the present study. Though, differences in study populations, rest duration, and the exercise protocol used may explain discrepant findings. Our results are also lower than the average (22.9 ± 2.1 ml/kg/min) and peak (35.9 ± 4.1 ml/kg/min) VO_2 responses during 3 sets of 10 repetitions of body weight burpees with 2 min rest in the same study. Interestingly, our average and peak VO_2 responses more closely match those of squat (19.6 ± 1.8 and 32.5 ± 5.0 ml/kg/min, respectively) and deadlift (18.9 ± 3.0 and 31.2 ± 5.1 ml/kg/min, respectively), performed for 3 sets at 75% 1RM for up to 10 repetitions.[25] Our average VO_2 responses for males and females are also more closely aligned to battle rope training with 2 min rest duration (20.7 ± 2.5 ml/kg/min and 18.0 ± 4.0 ml/kg/min, respectively) than 1 min rest (27.0 ± 3.3 ml/kg/min and 24.1 ± 4.2 ml/kg/min, respectively) when performed for 30 sec rounds at a standardized cadence of 45 repetitions per round, alternating intraset with single and double arm exercise.[19] Shorter rest duration typically results in greater metabolic responses to exercise.[28] Differences may be explained, at least in part, by dissimilar sampling frequencies utilized with indirect calorimetry.[23] Though, when taken together, it appears that rope climbing ergometry elicits a lower VO_2 response compared to battle rope training. The present study observed higher average and peak VO_2 in males compared to females. This is consistent with previous studies which have also shown greater VO_2 responses in males during rope HIIT exercise using double arm movements only [14] and a combination of single and double arm.[19,25] Previous studies have shown beneficial effects of battle rope training on physical performance.[12,13] However, no studies have investigated the performance benefits using rope climbing ergometry as a training modality, which represents a necessary future area of work.

In the present study, BLa increased significantly following exercise. Other studies investigating rope HIIT in a mixed sample of males and females have demonstrated slightly higher post-exercise blood lactate concentrations compared to the present study.[14] Though, these differences could be due to methodological differences as the present study analyzed blood lactate 2 min

post exercise while Fountaine and Schmidt utilized the peak concentration from samples taken at 1- and 2-min post exercise. We observed significantly greater post-exercise BLa in males (11.7 ± 2.8 mmol) compared to females (7.9 ± 2.0 mmol), which is consistent with findings from other studies.[19,29] Indeed, Ratamess et al, reported significantly higher post-exercise BLa in males immediately after a battle rope protocol using the same work:rest ratio as the current study.[19] BLa was also reported to be higher in males than females after both upper and lower body incremental exercise in cross-country skiers.[29] In contrast, Fountaine and Schmidt reported no differences in post-exercise BLa between males and females, when using a 15:45 second work:rest ratio. [14] However, these discrepant results may be attributed to the different work:rest ratio used in that study. The sex differences observed are likely due, in part, to known differences in substrate metabolism between the sexes whereby females have a greater reliance on fat compared to males, promoting carbohydrate sparing.[30] This claim is supported by the trend toward a higher RER in males, indicating greater reliance on carbohydrates for fuel. Despite the greater BLa response in males, no differences in RPE were observed between the sexes which indicates RC-HIIT was perceived similarly. This finding is in agreement with others reporting greater BLa without perceptual differences between males and females. [19]

Exercise enjoyment is a key factor in long term adherence [6,10]. In the present study, the average PACES score was 101.5 ± 15.9 out of 126, with similar scores between sexes. These findings are consistent with other studies examining various HIIT styles and suggest that RC-HIIT is an enjoyable exercise modality. Prior research has demonstrated that HIIT is perceived as equally or more enjoyable than moderate-intensity continuous exercise (MICT).[31] Indeed, these authors reported significantly higher PACES scores following a cycling HIIT workout (103.8 ± 9.4) versus a MICT workout (84.3 ± 19.1). Hoekstra et al examined the enjoyment of an arm crank ergometer HIIT workout and reported a PACES score of 90.2 ± 14.2,[32] suggesting that RC-HIIT may be more enjoyable compared to arm crank ergometer HIIT. The high PACES score observed in the present study suggests that RC-HIIT is an enjoyable modality of exercise, potentially enhancing long term adherence and subsequently promoting improved health and performance outcomes.[33]

In conclusion, rope climbing ergometry is an exercise modality that is becoming increasingly accessible to the general population and likely offers a safer alternative to traditional rope climbing. The results of the present study suggest that RC-HIIT induces physiological responses indicative of moderate- to vigorous-intensity exercise, which may lead to positive health and performance adaptations over time. Furthermore, the findings suggest that RC-HIIT is an enjoyable exercise modality, which may increase long term adherence. RC-HIIT may be an effective form of exercise for health and fitness professionals seeking low impact, upper body modalities. Future research should explore the health and performance adaptations resulting from rope climbing ergometry training, as no data currently exist on its long term benefits. Additionally, studies should compare these long term benefits to other training modalities.

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References

1. van Baak MA, Pramono A, Battista F, et al. Effect of different types of regular exercise on physical fitness in adults with overweight or obesity: Systematic review and meta-analyses. *Obes Rev*. 2021;22(Suppl4):e13239. https://doi.org/10.1111/obr.13239

2. Garber CE, Blissmer B, Deschenes MR, et al. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults. *Med Sci Sports Exerc*. 2011;43(7):1334-1359. https://doi.org/10.1249/MSS.0b013e318213fefb

3. Liguori G. *ACSM's Guidelines for Exercise Testing and Prescription*. 11th ed. American College of Sports Medicine; 2021.

4. Elgaddal N, Kramarow EA, Reuben C. *Physical Activity Among Adults Aged 18 and Over: United States, 2020*.; 2022. https://doi.org/10.15620/cdc:120213

5. Burgess E, Hassmén P, Pumpa KL. Determinants of adherence to lifestyle intervention in adults with obesity: A systematic review. *Clin Obes*. 2017;7(3):123-135. https://doi.org/10.1111/cob.12183

6. Sherwood NE, Jeffery RW. The behavioral determinants of exercise: implications for physical activity interventions. *Annu Rev Nutr*. 2000;20:21-44. https://doi.org/10.1146/annurev.nutr.20.1.21

7. Burgomaster KA, Howarth KR, Phillips SM, et al. Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. *J Physiol*. 2008;586(1):151-160. https://doi.org/10.1113/jphysiol.2007.142109

8. Gillen JB, Gibala MJ. Is high-intensity interval training a time-efficient exercise strategy to improve health and fitness? *Appl Physiol Nutr Metab*. 2014;39(3):409-412. https://doi.org/10.1139/apnm-2013-0187

9. Oliveira BRR, Santos TM, Kilpatrick M, Pires FO, Deslandes AC. Affective and enjoyment responses in high intensity interval training and continuous training: A systematic review and meta-analysis. *PLoS One*. 2018;13(6):e0197124. https://doi.org/10.1371/journal.pone.0197124

10. Santos A, Braaten K, MacPherson M, et al. Rates of compliance and adherence to high-intensity interval training: a systematic review and Meta-analyses. *I J Behav Nutr Phys Act*. 2023;20(1):134. https://doi.org/10.1186/s12966-023-01535-w

11. Maillard F, Pereira B, Boisseau N. Effect of high-intensity interval training on total, abdominal and visceral fat mass: A meta-analysis. *Sports Med*. 2018;48(2):269-288. https://doi.org/10.1007/s40279-017-0807-y

12. Bornath DPD, Kenno KA. Physiological responses to increasing battling rope weight during two 3-week high-intensity interval training programs. *J Strength Cond Res*. 2022;36(2):352-358. https://doi.org/10.1519/JSC.0000000000003470

13. Chen WH, Wu HJ, Lo SL, et al. Eight-week battle rope training improves multiple physical fitness dimensions and shooting accuracy in collegiate basketball players. *J Strength Cond Res*. 2018;32(10):2715-2724. https://doi.org/10.1519/JSC.0000000000002601

14. Fountaine CJ, Schmidt BJ. Metabolic cost of rope training. *J Strength Cond Res*. 2015;29(4):889-893. https://doi.org/10.1519/JSC.0b013e3182a35da8

15. Baláš J, Gajdošík J, Krupková D, et al. Psychophysiological responses to treadwall and indoor wall climbing in adult female climbers. *Sci Rep*. 2021;11(1):2639. https://doi.org/10.1038/s41598-021-82184-6

16. Gajdošík J, Baláš J, Draper N. Effect of height on perceived exertion and physiological responses for climbers of differing ability levels. *Front Psychol*. 2020;11. https://doi.org/10.3389/fpsyg.2020.00997

17. Aras D, Ewert AW. The effects of eight weeks sport rock climbing training on anxiety. *Acta Med Mediterr*. 2016;32(1): 223-230.

18. Siegel SR, Fryer SM. Rock climbing for promoting physical activity in youth. *Am J Lifestyle Med*. 2017;11(3):243-251. https://doi.org/10.1177/1559827615592345

19. Ratamess NA, Smith CR, Beller NA, Kang J, Faigenbaum AD, Bush JA. Effects of rest interval length on acute battling rope exercise metabolism. *J Strength Cond Res*. 2015;29(9):2375-2387. https://doi.org/10.1519/JSC.0000000000001053

20. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. *Int J Exerc Sci*. 2019;12(1):1-8. https://doi.org/10.70252/EYCD6235

21. Withers RT, LaForgia J, Pillans RK, et al. Comparisons of two-, three-, and four-compartment models of body composition analysis in men and women. *J Appl Physiol (1985)*. 1998;85(1):238-245. https://doi.org/10.1152/jappl.1998.85.1.238

22. Kendzierski D, DeCarlo KJ. Physical activity enjoyment scale: two validation studies. *J Sport Exerc Psychol*. 1991;13(1):50-64. https://doi.org/10.1123/jsep.13.1.50

23. Martin-Rincon M, Calbet JAL. Progress update and challenges on VO2max testing and interpretation. *Front Physiol*. 2020;11:1070. https://doi.org/10.3389/fphys.2020.01070

24. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*. 2001;37(1):153-156. https://doi.org/10.1016/S0735-1097(00)01054-8

25. Ratamess NA, Rosenberg JG, Klei S, et al. Comparison of the acute metabolic responses to traditional resistance, body-weight, and battling rope exercises. *J Strength Cond Res*. 2015;29(1):47-57. https://doi.org/10.1519/JSC.0000000000000584

26. Brewer W, Kovacs R, Hogan K, Felder D, Mitchell H. Metabolic responses to a battling rope protocol performed in the seated or stance positions. *J Strength Cond Res*. 2018;32(12):3319-3325. https://doi.org/10.1519/JSC.0000000000002903

27. Marín PJ, García-Gutiérrez MT, Da Silva-Grigoletto ME, Hazell TJ. The addition of synchronous whole-body vibration to battling rope exercise increases skeletal muscle activity. *J Musculoskelet Neuronal Interact*. 2015;15(3):240-248.

28. Ratamess NA, Rosenberg JG, Kang J, et al. Acute oxygen uptake and resistance exercise performance using different rest interval lengths: the influence of maximal aerobic capacity and exercise sequence. *J Strength Cond Res*. 2014;28(7):1875-1888. https://doi.org/10.1519/JSC.0000000000000485

29. Hansen LM, Sandbakk Ø, Ettema G, Baumgart JK. Upper- vs. lower-body exercise performance in female and male cross-country skiers. *Front Sports Act Living*. 2021;3:762794. https://doi.org/10.3389/fspor.2021.762794

30. Sims ST, Kerksick CM, Smith-Ryan AE, et al. International society of sports nutrition position stand: nutritional concerns of the female athlete. *J Int Soc Sports Nutr*. 2023;20(1):2204066. https://doi.org/10.1080/15502783.2023.2204066

31. Thum JS, Parsons G, Whittle T, Astorino TA. High-intensity interval training elicits higher enjoyment than moderate intensity continuous exercise. *PLoS One*. 2017;12(1):e0166299. https://doi.org/10.1371/journal.pone.0166299

32. Hoekstra SP, Bishop NC, Leicht CA. Can intervals enhance the inflammatory response and enjoyment in upper-body exercise? *Eur J Appl Physiol*. 2017;117(6):1155-1163. https://doi.org/10.1007/s00421-017-3602-4

33. Collado-Mateo D, Lavín-Pérez AM, Peñacoba C, et al. Key factors associated with adherence to physical exercise in patients with chronic diseases and older adults: an umbrella review. *Int J Environ Res Public Health.* 2021;18(4). https://doi.org/10.3390/ijerph18042023

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