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Article *in* The Journal of Strength and Conditioning Research · July 2013

DOI: 10.1519/JSC.0b013e3182a35da8 · Source: PubMed

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Abstract

Fountaine, CJ and Schmidt, BJ. Metabolic cost of rope training. *J Strength Cond Res* 29(4): 889–893, 2015—Rope training, consisting of vigorously undulating a rope with the upper body, has become a popular cardiovascular training choice in fitness centers and athletic performance enhancement facilities. Despite widespread use and growing popularity, little is known about the metabolic demands of rope training. Therefore, the purpose of this study was to quantify the cardiovascular and metabolic cost from an acute 10-minute bout of rope training. Eleven physically active participants used a 15.2-m rope anchored by a post, resulting in the participant holding 7.6 m of rope in each hand. The 10-minute protocol consisted of 15 seconds of vertical double-arm waves followed by 45 seconds of rest for 10 total repetitions. The metabolic cost was estimated from heart rate, lactate, resting O_2 uptake, exercise O_2 uptake, and excess postexercise O_2 consumption measurements. The average heart rate for the workout was 163 ± 11 $b \cdot min^{-1}$ with peak $\dot{V}O_2$ of 35.4 ± 5.4 $mL \cdot kg^{-1} \cdot min^{-1}$, and peak METs were 10.1 ± 1.6. Total energy expenditure was 467.3 ± 161.0 kJ. When expressed per unit of time, EE was 41.3 ± 14.1 $kJ \cdot min^{-1}$. The results of this study suggest an acute 10-minute bout of rope training in a vigorous-intensity workout, resulting in high heart rates and energy expenditure, which meet previously established thresholds known to increase cardiorespiratory fitness.

Key Words battle rope, cardiovascular conditioning, energy expenditure, undulation training

Introduction

A common challenge shared by personal trainers and performance enhancement specialists is the selection of exercises that address specific training goals, yet impart a novel challenge for athletes and clients (31). Thus, unique and innovative training techniques are continually introduced and disseminated via certifications, conferences, and webinars to provide fitness professionals with new ideas and training methodologies to consider implementing (4–7,10,14,31). Nonetheless, a notable lack of evidence-based research exists to either substantiate the effectiveness of many of these practices or validate hypothesized physiological adaptations (18).

Concurrently, the implementation of functional training methodologies that are purported to address athletic and tactical work capacity or metabolic conditioning for fat loss have increased in popularity (4,5,6,10,14,19,23,24). Modalities such as kettlebells, sandbags, and body-weight suspension training devices are commonplace within these types of workouts, and research has begun to emerge to demonstrate their potential effectiveness and utility (11,12,13,15,18,25,26). The use of this ground-based and dynamic total body approach to training has been defined by Martino and Dawes as dynamic specific action training (DSAT) and may have additional application to occupational and tactical athletes (19).

The use of large ropes, also known as battle ropes, Battling Ropes, or undulation training (4,5,6,16,19,21), is a relatively new modality within DSAT. Rope training typically consists of creating waves with 9-m to 15-m rope, 3–5 cm in diameter, which is looped around a fixed object. The rope is then vigorously undulated in a series of waves for a set interval, usually ranging from 10 to 30 seconds (5,10,18,19,21,23). Rope undulation options are truly limitless as the upper body may move with a fixed lower body, or undulations may occur with simultaneous movement in the lower body (4,16,19). Proponents of rope training highlight this challenging low-impact upper-body exercise as an intense metabolic workout that will result in improvements ranging from improved body composition to increases in aerobic and anaerobic capacity, and overall grip, shoulder, core, and total body conditioning (4,10,18,19,21,23). However, research has yet to substantiate the aforementioned benefits of rope training.

In addition to DSAT performed with tactical athletes, rope training has emerged in fitness centers and personal training studios as a popular group fitness activity (14,31). Many collegiate and professional strength and conditioning specialists have also begun to incorporate rope training with their athletes (5,6,10,21,23). However, no published research exists that documents either the acute or chronic effects of any aspect of rope training. Hence, recommendations for rope training exist solely at the expert opinion level of evidence-based practice hierarchy (3). Therefore, the purpose

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29(4)/889–893

Journal of Strength and Conditioning Research

Table 1. Physical characteristics of subjects ($n = 11$).

Variable	Total	Male	Female
Age, y	24.7 ± 1.9	24.8 ± 1.5	24.7 ± 2.4
Height, cm	172.3 ± 14.4	184 ± 12.3	162.5 ± 6.6
Body mass, kg	75.7 ± 18.3	91.2 ± 16.2	62.8 ± 4.5

Values are given as mean ± *SD*.

of this study was to quantify the cardiovascular and metabolic cost from an acute 10-minute bout of rope training in a sample of physically active male and female subjects.

Methods

Experimental Approach to the Problem

To establish descriptive data specific to rope training, recreationally trained subjects volunteered to perform a 10-minute rope-training workout. The rope-training protocol consisted of a 15-second interval of rope undulation, followed by 45 seconds of rest, repeated for 10 total repetitions. Heart rate, lactate, resting oxygen (O_2) uptake, exercise O_2 uptake, and excess postexercise O_2 consumption (EPOC) were all measured to help estimate total energy expenditure to determine the cardiovascular and metabolic cost of rope training.

Figure 1. Rope undulation starting position.

Subjects

A total of 11 physically active participants (5 male, 6 female, age 24.7 ± 1.9 years) were recruited for this study. Inclusion criteria sought physically active participants in good health. Eight subjects were former collegiate athletes, and all 11 subjects were currently involved in either recreational resistance training or running. This study was approved by the University's Institutional Review Board, and all subjects signed informed consent documents and a medical health history questionnaire before their participation. Participants with cardiorespiratory or other health problems that inhibited their ability to exercise were excluded from the study. All 11 participants completed the study with no injuries reported. Physical characteristics of the subjects are displayed in Table 1.

Procedures

Participants were instructed not to exercise on the day of testing and to fast at least 4 hours before testing. The subjects were acquainted with the rope training protocol on the day of testing by a Certified Strength and Conditioning Specialist (CSCS) with experience in rope instruction. All subjects demonstrated rope technique deemed acceptable by the CSCS before data collection commenced. Testing procedures began when subjects were seated in a chair, fitted with a mask and headgear, and resting O_2 uptake was recorded and averaged over a 5-minute period (28,29). Resting blood lactate was collected after the resting O_2 measurement was completed. At the end of the 5-minute resting baseline measurement period, the rope protocol commenced.

All participants used a nylon rope 15.24-m long, weighing 16.33 kg, and 3.81 cm in diameter (Rope Factory 2u2, Lake Charles, LA, USA). The rope was anchored at the base of a post, resulting in the participant holding 7.62 m of rope in each hand. The 10-minute rope protocol consisted of 15 seconds of vertical double arm waves followed by 45 seconds of rest for 10 total repetitions. Subjects began in an athletic position, feet shoulder width apart, with the trunk flexed forward to approximately 30–45° angle. Subjects held the ends of the rope with a neutral grip, with the arms straight and relaxed at their side (Figure 1). When performing the vertical double arm waves, the subjects were coached to use minimal lower body and trunk movement as to generate the waves primarily through shoulder flexion when raising the ropes and shoulder extension when crashing the ropes to the floor (Figure 2). The total number

Figure 2. Rope undulation midpoint.

of rope oscillations was recorded for each 15-second interval. As there is no singular standardized method for rope training, a 1:3 work-to-rest ratio was selected, consistent with anaerobic energy system training guidelines (8). After the 10-minute rope protocol was complete, participants were seated and postexercise O_2 was recorded until 2 consecutive measurements were within ±5% of resting O_2 uptake, with the postexercise O_2 used to calculate EPOC (17). Peak lactate measurements were taken at 1 and 2 minutes postexercise completion, with the highest concentration recorded (28,29).

Heart rate, resting O_2, exercise O_2, and EPOC were measured via indirect calorimetry with a metabolic cart (Parvo Medics True One 2400, Sandy, UT, USA) in 15-second sampling periods. Age-predicted maximum heart rate was estimated using the Gellish formula, $206.9 - 0.67 \times \text{age}$ (1). All blood-lactate measurements were recorded in duplicate using 2 handheld lactate analyzers (Lactate Plus Meter; Nova Biomedical, Waltham, MA) and were averaged for data analysis.

Aerobic energy expenditure was estimated at 1 L O_2 = 21.1 kJ (22). To estimate anaerobic energy expenditure, the authors utilized non–steady-state O_2 uptake measurements methods previously described by Scott et al. (27,28,29,30). Anaerobic energy expenditure was determined from the difference between peak and resting blood lactate measures, multiplied by body weight, then by 3.0 mL of O_2 (22). Conversions to O_2 equivalents were subsequently converted to kJ as 1 L of O_2 = 21.1 kJ (26,27,28,29). Resting O_2 and EPOC were converted to energy expenditure as 1 L of O_2 = 19.6 kJ to dismiss the glycolytic component from the O_2 measure (27,28,29,30). Total energy expenditure was calculated by summing aerobic energy expenditure, anaerobic energy expenditure, and EPOC (27,28,29,30).

Table 2. Descriptive cardiovascular and metabolic variables of rope training.

Variable	Total	Male	Female	p Value
Aerobic EE, kJ	362.4 ± 128.3	487.6 ± 64.0*	258.1 ± 30.3	≤0.001
Anaerobic EE, kJ	60.0 ± 14.1	62.5 ± 11.5	41.3 ± 6.8	0.005
EPOC EE, kJ	54.0 ± 22.2	72.1 ± 16.4	38.9 ± 13.3	0.005
Total EE, kJ	467.3 ± 161.0	622.2 ± 85.5*	338.3 ± 44.8	≤0.001
EE $kJ \cdot min^{-1}$	41.3 ± 14.1	54.9 ± 7.5*	29.9 ± 3.2	≤0.001
Peak lactate, mmol	11.9 ± 1.4	11.7 ± 1.5	12.1 ± 1.5	0.668
EPOC length, min	13.4 ± 4.1	13.6 ± 1.6	13.3 ± 5.6	0.933
Peak exercise $\dot{V}O_2$, $ml \cdot kg^{-1} \cdot min^{-1}$	35.4 ± 5.4	40.2 ± 3*	31.3 ± 2.9	0.001
Avg. exercise heart rate, $b \cdot min^{-1}$	163 ± 11	158 ± 14	165 ± 9	0.333
Peak exercise heart rate, $b \cdot min^{-1}$	178 ± 11	171 ± 11	183 ± 10	0.112
Peak METs	10.1 ± 1.6	11.5 ± 0.9*	9.0 ± 0.8	0.001

Values are given as mean ± *SD*.
EE, energy expenditure; EPOC, excess postexercise O_2 consumption.
The p values indicate differences between male and female subjects.
*Statistically significant with Bonferroni correction, $p \leq 0.0045$.

Statistical Analyses

All data were analyzed using IBM SPSS Statistics (version 21). Independent samples *t*-tests were used to analyze for gender differences between cardiovascular and metabolic measurements. Due to the large number of *t*-tests conducted, a Bonferroni correction was used to control the global Type I error rate at $\alpha = 0.05$ for the 11 between gender comparisons. Thus, statistical significance was defined as $p \leq 0.05/11 = 0.0045$. Cohen's d effect sizes were calculated ($M_1 - M_2$/pooled SD) to assess the meaningfulness of significant differences, with effect sizes >0.8 considered large (9).

Results

Descriptive statistics of the cardiovascular and metabolic variables of rope training are presented in Table 2. All data are presented as mean ± *SD*. Throughout the 10-minute testing protocol, subjects averaged 25 ± 4 rope undulations per 15-second work interval. Peak lactate levels were 11.9 ± 1.4 mmol, and average EPOC length was 13.4 ± 4.1 minutes. The average heart rate throughout the 10-minute session was 163 ± 11 bpm, which was 86% of age-predicted max. Peak heart rates reached 178 ± 11 $b \cdot min^{-1}$, 94% of age-predicted max, and peak METs averaged 10.1 ± 1.6.

Male subjects demonstrated significantly greater differences than females with large effect sizes for aerobic energy expenditure (487.6 ± 64.0 vs. 258.1 ± 30.3 kJ, $p < 0.001$, $d = 4.6$), total energy expenditure (622.2 ± 85.5 vs. 338.3 ± 44.8 kJ, $p < 0.001$, $d = 4.1$), $kJ \cdot min^{-1}$, (54.9 ± 7.5 vs. 29.9 ± 3.2, $p < 0.001$, $d = 4.3$), peak $\dot{V}O_2$ (40.2 ± 3 vs. 31.3 ± 2.9 $mL \cdot kg^{-1} \cdot min^{-1}$, $p = 0.001$, $d = 2.9$), and peak METs (11.5 ± 0.9 vs. 9.0 ± 0.8, $p = 0.001$, $d = 3.1$).

Discussion

The results of this study suggest that an acute 10-minute bout of rope training is a vigorous workout, resulting in very high heart rates (86% of age predicted max heart rate) and energy expenditure per unit of time (41 $kJ \cdot min^{-1}$). According to American College of Sports Medicine standards for cardiorespiratory fitness, the cardiovascular and metabolic demands of rope training would be classified as vigorous-intensity exercise (1,2); therefore, rope training may be most appropriate for individuals acclimated to high habitual amounts of vigorous-intensity exercise (1).

Significant differences in aerobic and total energy expenditure were observed between genders; however, this may be accounted for by the 30 kg average difference in weight between males and females. No significant gender differences were observed for peak lactate, EPOC length, average heart rate, or peak heart rate, suggesting that when controlled for bodyweight, males and females will have similar responses to the cardiovascular demands of rope training (20). Nevertheless, due to inherent male and female strength differences, the fitness professional may want to consider ropes of a smaller length and diameter when incorporating rope training with females.

As mentioned previously, no published research has examined rope training, making comparisons and conclusions rather limited at this time. However, the metabolic demands of rope training are most similar to other upper-body modes of cardiovascular conditioning, such as training with kettlebells. In a population similar to the present study, a 10-minute kettlebell routine consisting of 35-second swing intervals followed by 25-second rest intervals resulted in average heart rates of 180 ± 12 $b \cdot min^{-1}$, average $\dot{V}O_2$ of 34.1 ± 4.7 $mL \cdot kg^{-1} \cdot min^{-1}$, and $kJ \cdot min^{-1}$ of 52.3 ± 10.5 (15). Another similar kettlebell study found that a 12-minute kettlebell routine also resulted in similar metabolic demands, with an average $\dot{V}O_2$ of 26.5 ± 4.9 $mL \cdot kg^{-1} \cdot min^{-1}$and average heart rates of 165 ± 13 $b \cdot min^{-1}$ (13).

This study is not without limitations. First, the sample size was small and included only physically active young adults with an intercollegiate athletic background. Therefore, care is needed when generalizing the findings to other populations, particularly those who may be less active. Second, because no length or diameter of rope is standard when rope training, our findings may only apply to the use of 15.2-m length, 3.8-cm diameter rope. Ropes of differing diameter and length may result in a varied cardiovascular response, thus smaller sized ropes may be more appropriate dependent on the activity level and physical strength of the target population. Additionally, this study examined only a double arm wave method of rope undulation. Therefore, the results of this study may only apply to rope training in which the lower body is static. Third, the results of this study are from 1 acute bout of rope training. Therefore, it is not known at this time if an improved economy of rope training technique in latter phases of training would result in reduced cardiovascular and metabolic demands. Fourth, maximum heart rate data was predicted and not objectively determined via $\dot{V}O_2$ max testing, thus percent max values reported are duly noted as estimates. Furthermore, when compared with lower-body exercise, upper-body exercises produce greater physiologic strain (heart rate and blood pressure), thus it has been recommended that exercise prescriptions based on lower body cannot be applied to upper-body exercise (20). Due to the unique upper-body demands, rope training may place on an individual subjective workload assessments such as ratings of perceived exertion or talk tests may be more appropriate than percent max heart rate when initially assigning workload (1).

Collectively, the results of previous studies assessing metabolic demands of kettlebells and the current study using rope training provide evidence that these novel high-intensity upper-body exercises meet previously established thresholds known to increase cardiorespiratory fitness (1). Future research concerning rope training would be well served to investigate acute responses to various sized ropes and undulation protocols, along with chronic adaptations for individuals seeking changes in body composition, cardiovascular conditioning, or performance enhancement.

Practical Applications

Rope training provides a vigorous-intensity cardiovascular and metabolic stimulus, as demonstrated by elevated heart rate and energy expenditure per unit of time. Our results suggest that rope training can provide a high-intensity stimulus for strength and conditioning professionals who seek alternative or reduced impact-conditioning methods for athletes or clients.

Acknowledgments

The authors wish to thank Eric Adolph, CSCS, and Chris Sheckler, CSCS, for their assistance in data collection and instruction.

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