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## Energy Expenditure during Non-Traditional Physical Activities

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### ABSTRACT

**Sell K, Clocksin BD, Spierer D, Ghigiarelli J.** Energy Expenditure during Non-Traditional Physical Activities. **JEPonline** 2011;14(3):101-112. The purpose of this study was to compare the physical demands of a climbing activity (Prusik climbing) to Nintendo Wii boxing and brisk walking. Twenty-four college students ( $24 \pm 4$  years;  $175.4 \pm 8.6$  cm;  $78.9 \pm 17.4$  kg) attended four separate laboratory sessions: (a) 30 min of brisk walking; (b) maximal oxygen consumption ( $\text{VO}_2$  max) test; (c) 30 min of Nintendo Wii boxing; and (d) 30 min of Prusik climbing. During the walking, boxing, and Prusik climbing, heart rate (HR), rating of perceived exertion (RPE), oxygen consumption ( $\text{VO}_2$ ) and respiratory exchange ratio (RER) were recorded, from which average METs, total and average energy expenditure ( $\text{TEE}_{30}$  and  $\text{Aver-EE}_{1.0}$ ), and percentage of  $\text{VO}_2$  reserve ( $\%\text{VO}_2\text{R}$ ) were determined. Prusik climbing generated significantly higher average  $\text{VO}_2$ ,  $\%\text{VO}_2\text{R}$ , HR, RPE, METs,  $\text{TEE}_{30}$ , and  $\text{Aver-EE}_{1.0}$  compared to brisk walking and Wii boxing ( $P < 0.05$ ). Prusik climbing may provide an appealing alternative to traditional exercise programs for meeting current physical activity recommendations.

**Key Words:** Exercise, Prusik Climbing, ACSM Recommendations, Interactive Video-Games

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## INTRODUCTION

Regular participation in physical activity can potentially reduce the risk of obesity and obesity-related health concerns, such as some cancers and numerous chronic metabolic and cardiovascular diseases (3). Although recent research suggests a possible plateau in obesity prevalence rates among some child and adolescent populations (8,16,34), the number of overweight and obese adults and children in the United States has grown substantially in the last 30 yrs (35). The direct and indirect annual financial burden resulting from obesity-related conditions is estimated at greater than \$117 billion (42). Numerous reasons have been attributed to the aforementioned increases in obesity. These have included, but are not limited to, an increase in sedentary behaviors in children and adults (16,17), and a decrease in physical activity levels from child to early adulthood (10).

Given the documented increases in sedentary behavior and decline in physical activity levels in youth populations, practitioners have begun exploring new and innovative ways to encourage physical activity in youth populations. Enjoyment and perceived competence can impact readiness and frequency of participation in given physical activities, sports, and/or physical education opportunities (9,45). Physically interactive video games (PIVG), and adventure-based activities such as climbing, have emerged as popular alternatives to traditional physical activities. Research has suggested that several commercially available PIVG, such as Dance, Dance Revolution, Eye Toy, and Nintendo Wii, meet the intensity component of the current physical activity recommendations (20,28-30,40,43), but only a few studies have compared PIVG energy expenditure to other traditional modes of exercise (13,33,44). The disparity in current research may also be due to the lack of consistency in data collection protocols and the inadequate accumulation of data for a given population (e.g., children). Given the popularity of PIVG's among children, youth, and adults, investigating the utility of PIVG's to promote energy expenditure through increased physical activity is worthy of continued investigation (31).

In addition to the demands of rock climbing on muscle strength, grip strength, and aerobic fitness, it also elicits moderate to high heart rates and oxygen consumption levels (5,6,21,32,38). Rock climbing and other adventure-based activities provide a context by which adventure educators can encourage the development of team-building, communication, and improvements in various personal and social attributes (e.g., leadership qualities) (22). However, the energy expenditure associated with rock climbing frequently exceeds current recommendations for children and adults (5,38). Regular rock climbing, both indoor and outdoor, has been shown to generate improvements in both aerobic and anaerobic fitness (19,38,41).

The popularity of rock climbing has increased significantly over the last two decades (41). Moreover, the popularity of other adventure-based and school-based climbing activities for youth populations has also increased during this time (24). Adventure education courses and curricula consistent with state and national physical education standards have become popular in academic settings from elementary through to higher education institutions (26,27). Adventure education activities have been received with enthusiasm from student participants, teachers, and parents (27), although the documented evaluations of such programs are limited. Then, too, the potential ability for adventure-based activities other than rock climbing to meet energy expenditure and/or physical activity recommendations has not been examined, despite the popularity of adventure education in school settings and its accessibility as a recreational pursuit for youth and adult populations (41).

Similarly, adventure-based activities present a non-traditional, but potentially innovative way to promote physical activity in a number of different populations. Therefore the purpose of this study was to determine the average intensity level and energy expenditure achieved during a bout of a rope

climbing activity (Prusik climbing), relative to a popular PIVG (Nintendo Wii boxing) and a traditional form of exercise, brisk walking. It was hypothesized that Prusik climbing and Nintendo Wii boxing would exhibit higher energy expenditure and average intensity levels relative to brisk walking.

## **METHODS**

### **Subjects**

Twenty-four college students were recruited by word of mouth (snowball approach) from a northeastern university campus. The number of participants was determined using a power analysis (18) based upon average energy expenditure from walking and PIVG play in a population of college students in an earlier study (29), with a priori power set at 80% and an alpha level of 0.05. All participants were volunteers, non-smokers, and free from any condition that would have prevented a maximal effort during a graded exercise test. Participants were also free from any conditions that would limit moderate intensity upper body or lower body movements (e.g., shoulder or back injury). Participants were excluded if they had more than minimal experience playing Nintendo Wii boxing, given that research has suggested greater playing experience may elicit greater energy expenditure (40).

To our knowledge, this is the first study to scientifically evaluate energy expenditure related to Prusik climbing, however rock climbing experience has been shown to impact magnitude of energy expenditure (25). Therefore, participants were also excluded if they had any Prusik climbing experience. Prior to participation, each participant completed an informed consent, a medical health history questionnaire, and demonstrated that he or she did not have any health-related contraindications to physical activity. Approval from the University Institutional Review Board was acquired prior to study initiation.

### **Procedures**

Participants were asked to complete the study protocol during four separate laboratory sessions: 1) 30 min of brisk walking, 2) a maximal oxygen consumption test, 3) 30 min of Nintendo Wii Boxing, and 4) 30 min of Prusik climbing. The timeframe of 30 min was chosen for each bout to be consistent with the minimum amount of recommended aerobic-based physical activity over a 5-day period (2 hours 50 min recommended per week) for adults looking to maintain current health (43). During the first laboratory session, each participant completed the walking session and was provided the opportunity to practice and familiarize themselves with Nintendo Wii Boxing. The second, third, and fourth laboratory visits were randomized.

Participants were asked to avoid any strenuous physical activity 24 hrs prior to each laboratory visit and there was at least 24 hrs between laboratory visits. All laboratory visits were completed within 10 days. Participants were asked to wear shorts, t-shirts and athletic shoes for all sessions to avoid differences in thermoregulatory and metabolic responses due to clothing. Additionally, participants were asked to abstain from alcohol ingestion 48 hours prior to participation and to drink water liberally (two liters per day) one day prior to each testing session. Participants were asked to refrain from eating 2 hrs (not more than 8 hrs) prior to all testing sessions. Ambient temperature was maintained between 72°F and 78°F for all test sessions. All study sessions were supervised by a certified exercise professional.

### **Measures**

**Height and Weight.** A standard scale and stadiometer (Seca Mechanical Beam Medical Scale - Model 700, Hanover, MD) was used to determine weight in kilograms and height in centimeters to the closest tenth. Height and weight measures were recorded during the first laboratory visit.

**Resting Metabolic Rate.** To obtain resting metabolic rate, participants were instructed to sit and rest quietly for at least 15 min. Participants were fitted with a noseclip and mouthpiece (Hans Rudolph, Inc., Shawnee, KS) to measure oxygen consumption ( $\text{VO}_2$ ), relative  $\text{VO}_2$  (oxygen consumption in  $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ), and respiratory exchange ratio (RER) ( $\text{RER} = \text{VCO}_2/\text{VO}_2$ ; the ratio of carbon dioxide produced to oxygen consumed). Resting metabolic data were recorded each minute for 15 min using open circuit spirometry (Parvo Medics Metabolic Measurement System MMS 2400, Salt Lake City, UT). Heart rate (HR) was assessed using a Polar heart rate monitor (Polar CIC, Inc., NY). Throughout the resting protocol the participants sat in a quiet, comfortable, and darkened room. Resting data were collected during the second visit for all participants.

**Submaximal Treadmill Exercise Bout.** Participants were instructed to self-select (in order to replicate “real world” activity) a walking speed that they considered to represent a moderate intensity or “brisk” walking pace. Participants maintained their self-selected pace throughout a 30 min exercise bout. During each minute, metabolic data and HR were recorded using open circuit spirometry (Parvo Medics Metabolic Measurement System MMS 2400, Salt Lake City, UT). Rating of perceived exertion (RPE) on a (6-20) scale was also assessed at 5-min intervals by asking the participant to point to the value on a written RPE scale (6-20 scale) (7) indicative of subjective effort.

**Graded Exercise Test.** A graded treadmill exercise test was used to determine participants'  $\text{VO}_2$  max and document maximal exercise capacity. Each participant warmed-up by walking and jogging at a self-selected pace for 5 min. During the  $\text{VO}_2$  max test the treadmill was kept at the self-selected speed while grade increased by 2% every 2 min for the duration of the exercise test (modified version of the Costill and Fox [12] test). Metabolic data and HR were monitored continuously and recorded at the end of each minute using the same process described for the submaximal treadmill exercise bout. RPE was recorded every 2 min during the test. In accordance with recognized guidelines,  $\text{VO}_2$  max was identified at the point when at least three (or more) of the following criteria were met: (a) an RER of  $\geq 1.15$ ; (b) no further increase in HR with increasing intensity; (c) a plateau of  $\text{VO}_2$  with increasing workload ( $< 150 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ); (d) an RPE of  $> 17$  (6-20 scale); and (e) volitional fatigue (3,37).

**Nintendo Wii Boxing.** Participants completed 30 min of continuous Nintendo Wii Boxing. During game play, each participant faced a projector screen on which the game was displayed, while also holding and using the Wii remote and Nunchuk (one controller for each hand) throughout the exercise bout. The Wii remote serves as a motion sensor that allows the player to mimic the actions associated with a given sport/action displayed as an avatar on the screen. The swing of the upper body/arm is controlled by the player arm action and the avatar movement by the Wii system. Each exercise bout was played in the training mode (“punch-bag” option) for the first 15 min and in the “fight/competition” mode for the second 15 min.

To encourage continuous game play participants were instructed to select the on-screen tab “try again” as quickly as possible after completing a training session or fight. This approach has been used in previous research to help minimize any non-playing time and still reflect real-life play experience (40). In order to avoid interference during game play, the hose attached to the mouthpiece used for open-circuit spirometry was secured. Metabolic data and HR were monitored continuously and recorded at the end of each minute using the same process described for the submaximal treadmill exercise bout. RPE was also assessed at 5-min intervals during the exercise bout.

**Prusik Climbing.** Participants completed 30 min of continuous, self-paced, Prusik climbing. During climbing, each participant ascended and descended a 25' vertical climbing rope. Participants were outfitted with a climbing harness (Headwall Universal Harness) and attached to a vertical climbing

rope by a Prusik sling (Starlight Outdoor Education, minimum break strength 7000 lbs, safe working load 700lbs) using a Prusik hitch and a carabiner (Omega Jack Triple-Lok HMS) following manufacturer's guidelines for a front clip-in. A Prusik hitch was also used to attach a second Prusik sling for use as a foot hold. For ascent, participants stood on the foot hold, slid the Prusik hitch attached to their harness up the rope, sat so that their weight was applied to the Prusik hitch attached to their harness, and slid the foot hold upward (Figure 1). The process was reversed for descent.

Participants were provided with instruction and approximately 10 min of supervised practice time, by a trained instructor in Prusik climbing prior to completing the full bout. Practice continued until participants demonstrated the ability to successfully ascend and descend (average practice time was 4 min). Heart rate was monitored continuously, and RPE was assessed at 5-min intervals during the exercise bout. Open-circuit spirometry was conducted using a Cosmed K4b<sup>2</sup> portable gas analysis system (Cosmed K4b<sup>2</sup>, Rome, Italy), due to the nature of Prusik climbing and the accuracy and validity of this apparatus relative to standard laboratory-based approaches (15).



Figure 1 Legend. Prusik climbing ascent using foot hold and hitch attached to harness.

The K4b<sup>2</sup> unit (~925 grams) was harnessed to the participant's torso in a backpack fashion throughout the exercise bout. Participants wore a face mask attached to a turbine flowmeter that allowed for real-time collection of  $\text{VO}_2$  values (Figure 1). The apparatus was calibrated according to the manufacturer's instructions (Cosmed K4b<sup>2</sup>, Rome, Italy) prior to each climbing session. Data collection with the K4b<sup>2</sup> began when the participant was at the bottom of the rope prior to initiating the timed climb, and ended at the completion of the 30-min exercise bout (when the participant returned

to the ground following repetitive ascents and descents of the rope during throughout the exercise bout).

### Statistical Analyses

Demographic information was described and used for trend analyses. Variable differences between groups (submaximal walking, Wii boxing, and Prusik climbing) were examined using a one-way MANOVA and Tukeys post-hoc analyses. Dependent variables included average  $VO_2$  (Aver- $VO_2$ ), percentage of  $VO_2$  reserve ( $\%VO_2R$ ), total energy expenditure over 30 min ( $TEE_{30}$ ), average energy expenditure per minute (Aver- $EE_{1.0}$ ), RPE, RER, HR, and MET values. The statistical assumptions of normality, homogeneity of variance, and sphericity were satisfied. Unless specified otherwise,  $P < 0.05$  was used as an acceptable level of significance for all analyses. All statistical analyses were conducted using the PASW Statistics 17 software (SPSS Inc., Chicago, IL).

## RESULTS

All 24 college students (6 men, 18 women;  $24 \pm 4$  years;  $175.4 \pm 8.6$  cm;  $78.9 \pm 17.4$  kg) completed the  $VO_2$  max test and each of the physical activity bouts described earlier. Participants had an average  $VO_2$  max of  $45.4 \pm 7.6$  ml·kg<sup>-1</sup>·min<sup>-1</sup> and walked at an average speed of 4.1 mph during the brisk walking exercise bout. Descriptive data for each exercise variable is presented in Table 1. Sex differences were not analyzed due to the relatively small sample of men in the study.

Table 1. Exercise data (n = 24)

	Brisk Walking	Nintendo Wii Boxing	Prusik Climbing
HR (beats ·min <sup>-1</sup> )	117.8 ± 14.3	123.0 ± 17.6	148.7 ± 10.7*
RER	0.88 ± 0.05	0.88 ± 0.04	0.90 ± 0.07
Aver- $VO_2$ (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	16.6 ± 4.4	16.2 ± 5.7	22.7 ± 4.4*
$\%VO_2R$ (%)	41.2 ± 13.5	38.8 ± 11.8	55.1 ± 10.1*
RPE (1-10 scale)	3.3 ± 0.8	3.9 ± 1.0	6.6 ± 1.3*
$TEE_{30}$ (kcal·30 min <sup>-1</sup> )	190.1 ± 57.9	181.9 ± 62.3	265.6 ± 58.3*
Aver- $EE_{1.0}$ (kcal·min <sup>-1</sup> )	6.3 ± 1.9	6.1 ± 2.1	8.9 ± 1.9*
Aver-MET	4.8 ± 1.3	4.6 ± 1.6	6.5 ± 1.3*

Table 1. Values are mean ± standard deviation; \* $P < 0.05$  average; HR = heart rate; RER = respiratory exchange ratio; Aver- $VO_2$  = average oxygen consumption;  $\%VO_2R$  = percentage of oxygen consumption reserve; RPE = rating of perceived exertion;  $TEE_{30}$  = total energy expenditure over 30 min; Aver- $EE_{1.0}$  = average energy expenditure per min; Aver-MET = average metabolic equivalent value.

One-way MANOVA (Pillai's Trace) generated significant differences across the exercise modalities for the dependent variables analyzed ( $F=5.77$ ,  $P < 0.001$ ). The results for subsequent one-way ANOVAs for each dependent variable are presented in Table 2. Prusik climbing generated significantly higher Aver- $VO_2$ ,  $\%VO_2R$ ,  $TEE_{30}$ , Aver- $EE_{1.0}$ , RPE, HR, and METs, and compared to brisk walking and Wii boxing ( $P < 0.001$ ) (Tables 1 and 2). No significant differences were observed between walking and Wii boxing for any of the aforementioned variables ( $P > 0.05$ ).

Table 2. One-way ANOVA results for dependent variable differences between exercise modalities.

Variable	Exercise modality	
	<i>F</i> (2,69)	<i>P</i>
HR	31.43	<0.001
RER	1.14	0.325
Aver-VO <sub>2</sub>	13.06	<0.001
%VO <sub>2</sub> R	13.27	<0.001
RPE	62.49	<0.001
TEE <sub>30</sub>	14.41	<0.001
Aver-EE <sub>1.0</sub>	14.42	<0.001
Aver-MET	13.06	<0.001

Table 2. HR = heart rate; RER = respiratory exchange ratio; Aver-VO<sub>2</sub> = average oxygen consumption; %VO<sub>2</sub>R = percentage of oxygen consumption reserve; RPE = rating of perceived exertion; TEE<sub>30</sub> = total energy expenditure over 30 min; Aver-EE<sub>1.0</sub> = average energy expenditure per minute; Aver-MET = average metabolic equivalent value.

## DISCUSSION

This study compared the physiological responses of young adults during bouts of brisk walking, Nintendo Wii boxing, and Prusik climbing. In the present study, HR, EE, VO<sub>2</sub>, and RPE were significantly higher during Prusik climbing compared to walking or Wii boxing, but no differences were observed between Wii boxing and walking. Prusik climbing in this study also generated considerably higher EE and MET values than walking, stepping, or other PIVGs in previous research (2,4). Wii boxing in the current study generated both lower and higher Aver-EE<sub>1.0</sub> and %VO<sub>2</sub>R values than previous research (4,14,39).

The greater energy expenditure shown in Prusik climbing compared to Wii boxing and walking may be directly related to the nature of the activity. Prusik climbing involves physically moving the body with mechanical assistance provided by a climbing harness and footholds. The whole body is engaged in the movements required to successfully climb using the Prusik approach. Although the Wii apparatus provides an interactive atmosphere, the motion sensors are so sensitive that players may be tempted to take the path of least resistance while playing, such as twisting or rotating the wrist as opposed to swinging or punching with the arm or incorporating whole body movement. The participants were encouraged to play Wii boxing to the best of their ability and in a manner that would reflect real-world play. The variability in self-selected motion during Wii Boxing was important to explore via metabolic data collection. For these reasons, a direct comparison of Prusik climbing, Wii boxing, and walking was conducted, even though a considerable body of research has already documented energy expenditure values for various PIVG.

The recently updated physical activity recommendations issued by ACSM and the American Heart Association (AHA) expand on the original recommendations issued in 1995 (36). Specifically these updated recommendations state, "...all healthy adults aged 18-65 years need moderate-intensity aerobic (endurance) physical activity for a minimum of 30 min five days each week or vigorous-intensity aerobic physical activity for a minimum of 20 min on three days each week" (23, p. 1425). These guidelines were supported by similar recommendations issued in 2008 by the U.S. Department of Health and Human Services (43). Low-intensity is defined as below 3 METs, whereas moderate

intensity is defined as 40% to 59% of  $\text{VO}_2\text{R}$  or 3 to 6 METs and hard or relatively vigorous-intensity is defined as 60% to 84% of  $\text{VO}_2\text{R}$  (or above 6 METs), (3,23). Prusik climbing demanded a degree of effort consistent with moderate to hard intensity physical activity in the current study. Brisk walking could be considered a moderate level physical activity, and Wii Boxing considered low to moderate intensity, based on the  $\% \text{VO}_2\text{R}$  and MET levels achieved (Table 1).

Past studies have used an alternative extension of previous physical activity guidelines to compare energy expenditure outcomes between different modalities, specifically the amount of energy expended in 1 min and subsequently per hour ( $\text{kcal}\cdot\text{hr}^{-1}$ ) of engagement. Wii boxing in the current study expended  $6.1 \text{ kcal}\cdot\text{min}^{-1}$  which equates to  $366 \text{ kcal}\cdot\text{hr}^{-1}$ . This levels of caloric expenditure was considerably lower than the  $12.1 \text{ kcal}\cdot\text{min}^{-1}/730 \text{ kcal}\cdot\text{hr}^{-1}$  and  $7.2 \text{ kcal}\cdot\text{min}^{-1}/432 \text{ kcal}\cdot\text{hr}^{-1}$  previously documented (4,20). The intensity of boxing using a punching bag is approximately 6 METs (1,2), which is also higher than the average intensity during the simulated PIVG boxing in the current study (4.6 METs). The average intensity of the walking bout in the current study (4.8 METs) is similar to the intensity of brisk walking previously documented (5 METs) (1,2). The Prusik climbing session generated  $8.9 \text{ kcal}\cdot\text{min}^{-1}$  (equating to  $534 \text{ kcal}\cdot\text{hr}^{-1}$ ) and an average intensity of 6.5 METs - a significantly higher metabolic response than walking or Wii boxing. However, the metabolic cost of slow rope climbing has been approximated at close to 8 METs (1,2), suggesting that the self-selected pace at which participants completed this bout may have limited optimal caloric expenditure. Based on the results in the current study it would take an average of 23.5, 24.4, and 16.5 min to expend 150 kcal through brisk walking, Wii boxing, and Prusik climbing, respectively. The physical activities examined in this study represent safe approaches for achieving recommended levels of daily or regular physical activity for young adults. However, the results suggest that Prusik climbing may provide a greater metabolic stimulus. Consequently, Prusik climbing may be a more effective modality with regard to energy expenditure and subsequent weight management interventions.

The current data may be limited by the variability in the participants' effort during each exercise bout (i.e., each participant walked at his or her "true" brisk walking pace). To minimize this concern, each activity session was supervised by research personnel with expertise in the activity being performed. Further, the self-designated pacing and self-selected degree of effort was incorporated in an effort to encourage a real-life approach to physical activity. A portable metabolic system was used during the Prusik climbing bout due to mechanical limitations in using the stationary metabolic cart. Although a limitation, the portable system used in this study has been validated as a measurement tool for metabolic data collection relative to standard laboratory-based approaches (15).

Considerable research has been conducted on the physiological demands associated with PIVGs, but minimal research has been conducted on the metabolic demands of adventure-based activities, such as rope climbing. The current study may provide the foundation for exploring the metabolic demands of more diverse forms of adventure educational activities, such as high ropes activities. Exploring nontraditional means of acquiring physical activity, meeting or exceeding current physical activity guidelines (3,23), and motivating continued participation in lifetime physical activities is becoming increasingly important. Adventure-based activities, whether as part of physical education or community-based programs, present a safe, enjoyable, and challenging modality that can be adapted to meet the physical capabilities and goals of youth and adult populations.

## CONCLUSIONS

Although research suggests that obesity rates in youth populations are beginning to show a plateau, the number of obese adults and children is at an unprecedented high (11). Encouraging positive



activity behaviors is an important investment for physical educators and exercise professionals in addressing obesity trends and hypokinetic diseases. Prusik climbing demonstrated significantly higher energy expenditure and overall physical demand than Wii boxing and brisk walking, which could be beneficial for individuals interested in adventure-based activities as a means to acquire current physical activity recommendations (3,23). Despite the popularity, few studies have explored the physiological demands of adventure-based activities other than rock climbing. The growing interest in adventure programming and access to vertical climbing ropes in schools may facilitate the use of Prusik climbing as a means of achieving the recommended amount of daily physical activity.

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