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PHYSIOLOGICAL RESPONSES AND HEALTH BENEFITS OF INDOOR ROCK CLIMBING IN COLLEGE-AGED INDIVIDUALS

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ABSTRACT

Nicholson AE, Lopez SL, Burke JL, Emerson KJ, Mueggenborg RL, Dunbar JA. Physiological Responses and Health Benefits of Rock Climbing in College-Aged Individuals, *Journal of Undergraduate Kinesiology Research* 2007;2(2):1-11. Many health benefits are associated with regular physical activity. **Purpose:** The purpose of this study was to determine the physiological responses and health benefits of indoor rock climbing in college-aged, recreational climbers. **Methods:** Five male and five female subjects, ages 19-23, participated in a basic assessment (including VO_2max test) and a climbing session. **Results:** Total energy expenditure (EE), total percent heart rate reserve (%HRR), total percent VO_2 reserve (%VO_2R), climbing %HRR, and climbing %VO_2R were measured while climbing. Mean values for total EE, total %HRR, total %VO_2R, climbing %HRR, and climbing %VO_2R were 202.89 ± 50.60, 34.90 ± 8.29, 21.90 ± 4.18, 71.10 ± 8.94, and 48.20 ± 7.90 respectively. **Conclusion:** Indoor rock climbing meets the ACSM intensity guidelines (%HRR and %VO_2R) for physical activity and complies with the ACSM recommendations for energy expenditure in college-aged, recreational climbers.

Key Words: Alternative exercise, adventure sports, energy expenditure, heart rate reserve, VO_2reserve

INTRODUCTION

Physical inactivity is considered to be a major risk factor for numerous diseases. Some of the many benefits seen with participation in physical activity include a decrease in the risk of all-cause mortality, cardiovascular disease, Type 2 diabetes mellitus, and improvement in physiological, metabolic, and psychological capabilities (1,2). These benefits follow the dose-response relationship, an inverse relationship between the amount of exercise and the risk of developing the aforementioned diseases (1).

Multiple organizations have established guidelines for achieving optimal benefits from physical activity and exercise. The American College of Sports Medicine (ACSM) recommendations state that an individual should exercise for 20-60 minutes at 40-85 percent of their heart rate reserve (HRR) or VO_2 reserve (VO_2R), three to five days per week (3). A minimum energy expenditure (EE) of 150 kcal per day, amounting to 1000 kcal per week, is also recommended by ACSM (2,3,4). HRR is the difference between maximal heart rate and resting heart rate for a given individual. Percent HRR (%HRR) is the portion of one's HRR achieved by an activity. VO_2 is a measure of the amount of oxygen used by the muscles in the body; VO_2max describes the oxygen uptake consumed and utilized by the muscles during maximal exercise. VO_2R is the difference between VO_2max and resting VO_2, and percent VO_2R (%VO_2R) is the portion of one's VO_2R utilized during an activity. The U.S. Surgeon General guidelines suggest 30 minutes of moderate-intensity (40-60 percent VO_2R or HRR) physical activity on most, if not all, days of the week (2).

More than 60% of American adults and more than 50% of young adults (ages 12-21) do not engage in regular, vigorous activity (2). This is perhaps due in part to a lack of enjoyment experienced from participation in traditional forms of physical activity (such as walking, running, swimming, and cycling). One possible way in which to increase the number of individuals involved in regular physical activity is to emphasize that the health benefits of traditional exercise can often be found in alternative forms of exercise such as snowshoeing, kayaking, cross-country skiing, and surfing. Individuals who find such activities more engaging may be more willing to adhere to an exercise program because of the enjoyment of participating in the activity. Indoor rock climbing is another increasingly popular mode of physical activity that is believed to elicit the physiological effects required to produce health benefits.

Although there is limited research on the specific physiological benefits of rock climbing, the research that has been conducted has positive results. Watts & Drobish found that, for experienced climbers, continuous rock climbing is capable of producing positive changes in aerobic fitness (5). Additionally, it is not necessary to climb difficult routes (angled at 80-90 degrees) in order to achieve aerobically significant VO_2 levels of 40-60 percent of VO_2R (5). Individuals who wish to try rock climbing, but do not feel they have an adequate level of aerobic capacity will be encouraged to know that high aerobic power is not a determining factor in climbing performance. Because rock climbing typically taxes anaerobic systems, climbers do not typically possess extremely high aerobic power (averaging between 52 and 55 ml/kg/min) (6). During climbs of 5.11 on the Yosemite Decimal Scale (YDS), Watts found VO_2 averages ranging from 20-25 ml/kg/min with peaks over 30 ml/kg/min, and with energy expenditure rates close to 10 kcal/min (6). The YDS is the rock climbing grading system most commonly used in North America; it consists of five classes (7). Class five describes what is generally considered to be rock climbing, a nearly vertical climb requiring skill to proceed (7). This class is further divided to rate the specific difficulty of a particular climb (example: a 5.6 climb is easier than a 5.10a climb).

Individuals may feel that they do not have the proper body type to be successful in rock climbing. However, whether individuals with certain body types are more inclined to try rock climbing, or whether rock climbing produces certain body types must be further researched. Elite competitive sport climbers typically have a small frame, an extremely lean body composition, and a high strength to body mass ratio (6,8,9). On the other hand, Grant, Hynes, Whittaker, & Aitchison found no difference in percent body fat between elite, recreational, and non-climbers (10). Height, arm length, and body weight are traditionally thought to be important for climbing performance (6). However, Mermier, Janot, Parker, and Swan found that the variables which explain the greatest difference in sport climbing abilities are actually trainable (ex. flexibility, strength) rather than anatomical (ex. height, arm length) (11). Therefore, individuals should not be discouraged from rock climbing based on their body type.

More research needs to be done on the benefits of rock climbing for novice climbers compared to advanced climbers. The purpose of this study is to determine the physiological responses and health benefits of indoor rock climbing in recreational, college-aged climbers. We hypothesized that indoor rock climbing would fulfill the ACSM energy expenditure and exercise intensity recommendations for healthy college-aged individuals to improve or maintain cardiovascular fitness.

METHODS

Subjects

Five male and five female college-aged (19-23 years), recreational climbers were used for this study. Mean (±SD) age, height, and weight of participants was 20.70 ± 1.16, 172.81 ± 7.68, and 72.45 ± 9.09 respectively. Participants were selected by word of mouth. To be considered a recreational climber, individuals must have climbed more than five routes. Individuals who were able to complete a route rated at 5.10 on the YDS were not allowed to participate. Prior to collecting the data, the study was approved by the University of Wisconsin – Eau Claire's Human Subjects Institutional Review Board. In addition, all subjects signed a written informed consent before volunteering for the study. All individuals filled out a health history questionnaire to determine if they were physically capable of meeting the demands of the study.

Procedures

Participants were required to participate in two testing sessions. The first session consisted of a basic assessment including a health history questionnaire, height and weight, grip strength, seven-site skinfolds, resting blood pressure (BP), resting heart rate (HR), resting VO_2, maximum HR, and VO_2max measurements. A Detecto Balance Scale (Webb City, MO) was used to assess weight and a stadiometer, by Seca (Hamburg, Germany), was used to measure the height of the subjects. The 5001 handgrip dynamometer (Takei Scientific Instruments, Co. Ltd., Tokyo, Japan) was used to measure the approximate muscular strength of each individual. A Lange Skinfold Caliper (C-130), manufactured by Beta Technology Inc. (Cambridge, MD), was used to determine percent body fat using seven-site skinfolds. Blood pressure was measured using a 752M sphygmomanometer and a stethoscope, both produced by The American Diagnostic Corporation, Ltd. (West Babylon, NY). A T31 Heart Rate Monitor Transmitter, manufactured by Polar Electro Inc. (Woodbury, NY), was worn by each participant to obtain HR for the VO_2max test and the climbing session. The $K4b^2$ portable metabolic analyzer by Cosmed Pulmonary Function Equipment (Rome, Italy) was used to collect all VO_2 measurements for both testing sessions. The VO_2max test was run on a TMX 425 CP treadmill manufactured by Full Vision Inc. (Newton, KS) using the Modified Balke protocol. Participants were advised to refrain from participating in strenuous physical activity, drinking alcohol, and consuming excessive caffeine for 24 hours prior to the VO_2max test. After the test was complete, the subject cooled down by walking on the treadmill for an additional five minutes. Data was also collected during the cool-down.

Following the VO_2max test, the subjects were required to wait a minimum of 24 hours before participating in the climbing session. Again, participants were advised to refrain from participating in strenuous physical activity, drinking alcohol, and consuming excessive caffeine for 24 hours prior to the testing session. The climbing portion took place at a 28 foot tall, 65 foot long indoor wall created by Adventure Based Experimental Educators (ABEE) Inc. (Oconomowoc, WI). The climbing surface consisted of molded 4x4-foot panels taken from natural granite impressions. Each subject was provided with a Petzl, "Gym" harness (Clearfield, UT) and Fiveten, "Rental Summit" climbing shoes (Redlands, CA) to use for the session. The climbing ropes used for this portion of the study were 10.7 mm dry core dynamic Sterling ropes (Scarborough, ME) and were new as of January 2007. Tuber "HB Sheriff" belay pieces by Hugh Banner (Bangor, North Wales) were also utilized for safety purposes. All carabineers were “Liberty Steel HMS” carabineers by Liberty Mountain, (Salt Lake City, UT). Neither hand chalk nor similar substances were allowed while climbing.

After putting on the Polar heart rate monitor, the climbing harness, and the portable metabolic analyzer, the subject walked for five minutes to warm up. Following the warm-up, the individual was instructed to climb the designated route. Placed for the specific use of this study, none of the subjects had previously climbed the route and did not find out which route they were going to climb until they were about to begin their first attempt. In order to create a feasible challenge for all participants, a 5.7 route was chosen for this investigation. A completed climb was defined as ascending to the top, using the correct holds, and tapping the ceiling at the top. A fall was defined as losing all contact with the wall, at which point the attempt was considered failed and the subject was lowered to the ground. Upon returning to the ground after a failed or a successful attempt, the subject was given seven minutes to rest. Rating of perceived exertion (RPE) while climbing was measured using a 1-10 scale following each completed attempt. Subjects were allowed five attempts to complete four climbs. Data was collected constantly from the beginning of the warm-up phase until the end of the seven minute rest period following the final climb.

Statistical Analyses

SPSS 14.0 (Chicago, IL) was used to calculate means and standard deviations for all variables.

RESULTS

Means and standard deviations found during the basic assessment are presented in table 1. The minimums, maximums, and means (with standard deviations) of all subjects are reported in table 2. The physiological responses were similar between the eight subjects who completed all four climbs and the two who did not. Thus, for clarity purposes, the data were pooled. Total EE refers to the total energy expenditure for the whole climbing session (approximately 55 minutes) in kcals. Total percent heart rate reserve (%HRR) describes the average percent of heart rate reserve (HRR = maximal HR –resting HR) throughout the whole session. Total %VO_2R values indicate the average percent of VO_2 reserve (VO_2R = VO_2max – resting VO_2) over the whole session. Climbing %HRR refers to the average percent HRR only while the individual was climbing (not including warm-up or rest periods). Climbing %VO_2R describes the average percent of VO_2R only while the individual was climbing. Figure 1 illustrates the means of %HRR and %VO_2R. Additionally, figure 2 shows HR and VO_2 measurements of a representative climber who completed the climbing portion in four attempts. The elevated portion at the beginning is data from when the individual was warming up. The peaks in HR and VO_2 occur while the individual is climbing.

Table 1. Basic assessment information for all subjects.

Variable	Mean ± SD
Age (yrs)	20.70 ± 1.16
Height (cm)	172.81 ± 7.68
Weight (kg)	72.45 ± 9.09
Body fat (%)	17.19 ± 8.93
Resting HR (bpm)	72.90 ± 9.99
Resting VO_2 (mL/kg/min)	3.50 ± 0.96
Max HR (bpm)	193.70 ± 12.94
VO_2max (mL/kg/min)	50.73 ± 9.73
Dominant grip (kg)	46.20 ± 9.67
Grip sum (kg)	89.90 ± 19.94

Subject during VO_2max testing.

Table 2. Results of climbing session for all subjects.

	Minimum	Maximum	Mean ± SD
Total %HRR	26	50	33.63 ± 3.00
Climbing %HRR	59	87	69.50 ± 3.32
Total %VO_2R	17	29	21.50 ± 1.27
Climbing %VO_2R	36	58	48.63 ± 2.44
Climbing RPE	2	10	3.89 ± 1.56
Total METs	2.94	4.67	3.83 ± .46
Climbing METs	4.91	8.69	7.24 ± 1.12
Total EE	135.80	302.25	202.89 ± 17.72

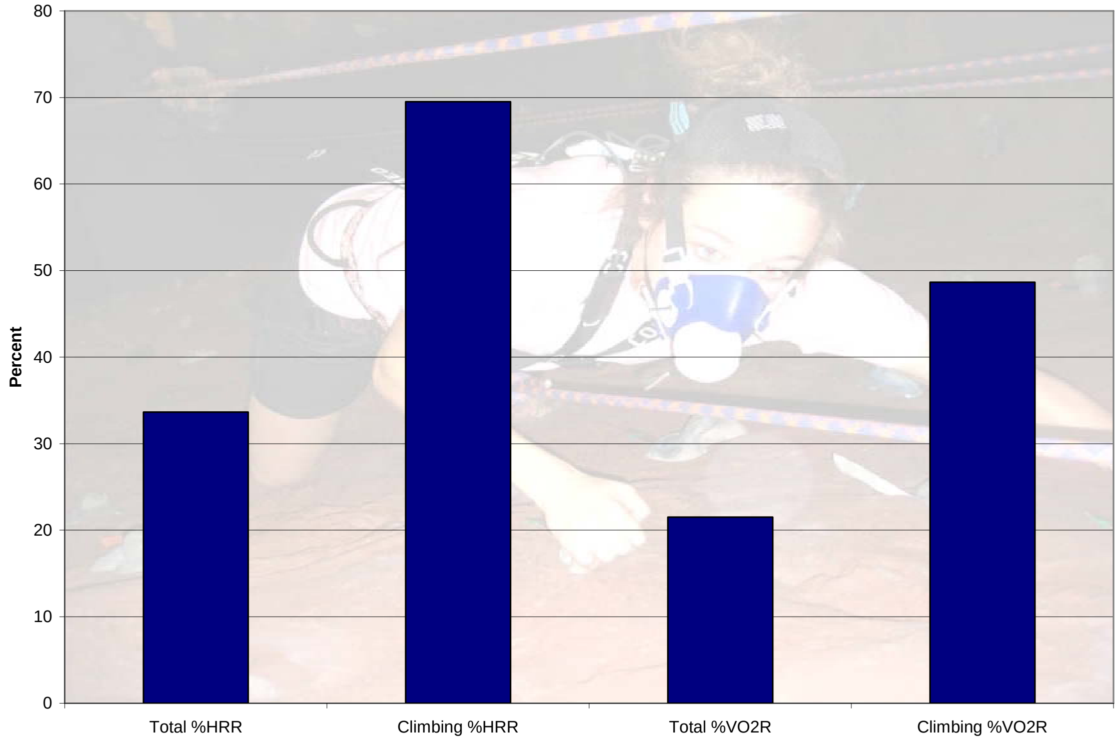

Figure 1. Mean values of %HRR and %VO_2.

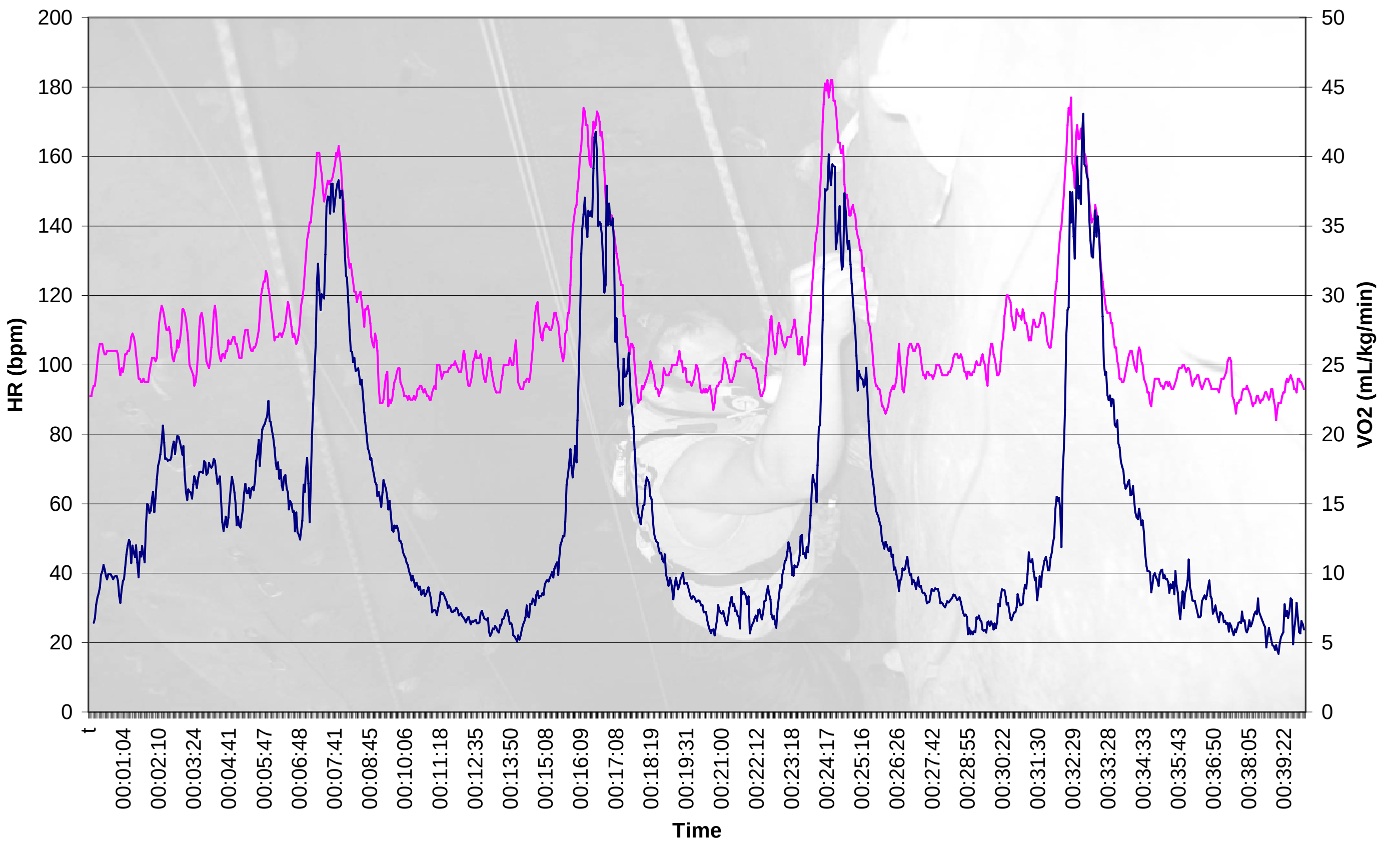

Figure 2. HR (purple) and VO_2 (blue) over time.

DISCUSSION

The purpose of this study was to determine the health benefits and physiological effects of indoor rock climbing on college-aged individuals with limited climbing experience. We hypothesized that indoor rock climbing would fulfill the ACSM exercise intensity and energy expenditure recommendations for healthy college-aged individuals for improving or maintaining cardiovascular fitness.

Gender differences

Previous research has demonstrated that there are no significant differences in physiological responses from climbing between males and females (12,13). For this reason, the data was combined with no reference to gender.

Heart rate responses

Even though the total %HRR in this study was not within the ACSM guidelines, the climbing %HRR was. This is not surprising because rock climbing involves short bursts of high intensity which predominantly utilize anaerobic energy systems. It is possible that using shorter rest periods would have helped to keep %HRR elevated enough to stay within ACSM recommendations. Having an individual climb more difficult routes and/or more times throughout the exercise session would also produce higher levels of %HRR.

It is an important finding that the act of climbing does produce %HRR values within ACSM guidelines. Furthermore, it is not necessary to complete a given route in order to achieve cardiovascular gains. This is evidenced by the similar HR responses observed in the two subjects who were unable to complete four climbing trials and those who did complete each climb. Therefore, the cardiovascular benefits of rock climbing are not dependent on climbing ability.

Other research confirms the results of the present study and provides interesting additional information. Billat, Palleja, Charlaix, Rizzardo, & Janel found that climbing produced 85.5 ± 3.2 percent of HR_{max} (14). Climbing was also found to have a significantly greater maximal HR at VO_2max during climbing versus rowing (15). A study done on recreational kayaking found a mean %HRR of 40, which falls between our total %HRR and our climbing %HRR (16).

VO_2 responses

The mean value of climbing $\%VO_2R$ did indeed fulfill the ACSM guidelines. The mean value of total $\%VO_2R$ did not, likely for the same reasons as listed for heart rate responses. Again, attempting more difficult routes, decreasing rest time, and/or doing laps would likely increase total $\%VO_2R$ values. Similar to our study, Billat et al. found route climbing to produce 45.6% of treadmill VO_2max values (14). Mermier, Robergs, McMinn, & Heyward found that the increase in VO_2 for indoor rock climbing was similar to moderate-paced walking (12). Watts and Drobish found that rock climbing could elicit VO_2 values high enough to produce positive modifications in aerobic fitness (5).

Comparing VO_2 responses to other forms of exercise allows perspective to take place. Brahler found VO_2max values to be significantly higher for VersaClimber (a type of climbing treadmill) than for treadmill running or rowing ergometry (15). Utilizing rotating toe-cord and fixed toe-cord snowshoe systems at average speeds of 3.96 and 2.86 km/h respectively, produced VO_2 values that were 56% and 60% of VO_2max respectively (17).

RPE responses
Rating of perceived exertion (RPE) data were collected in order to establish an alternative method of monitoring intensity in rock climbing as an exercise modality. Mean RPE was 3.89 ± 1.56, which supports a moderate intensity of exercise while climbing. RPE is necessary to assist in the practical application of rock climbing as an alternative form of exercise, specifically for implementation of school-based activity programs. Individuals who do not have access to a heart rate monitor will still be able to determine their exercise intensity by following the RPE scale.

MET values
The mean metabolic equivalent value while rock climbing was found to be 7.24 ± 1.12. This value corresponds to walking at approximately 4 km/hr on a grade of 7.5% and stair stepping at a rate of 20 steps/min with a step height of 0.356 m (18).

Energy expenditure
Moderate levels of physical exertion are reached during rock climbing. This is evidenced by our findings that mean total EE (202.89 ± 50.60) is higher than the ACSM guidelines. Furthermore, additional caloric expenditure may result from an increase in climbing difficulty, frequency, and/or length of time. According to a study conducted by Watts and Drobish, there is no significance in EE among angles of climbing (5). However, when relative to distance, EE increased significantly when the angles of the climb went beyond vertical (5).

Variability of climbing ability
It is important to highlight the broad definition of a recreational climber used in this study. Any individual who had climbed up a rock face (real or artificial) at least five times, but was unable to climb above a 5.9 route was eligible to participate. As a result, some subjects had climbed only five times before, whereas others had completed 5.8's and 5.9's. A broad definition was used intentionally in order to obtain individuals who were relatively familiar with rock climbing, but were still considered novice climbers. This would make our results more applicable to our target population, individuals who are looking for new and alternative forms of exercise. It must also be noted that RPE data may have been influenced by variations in climbing ability as some subjects were more experienced climbers, resulting in a lower RPE than those with little climbing experience.

Resting time
Subjects received approximately seven minutes of resting time between attempts. This was to allow muscles to fully recover from each climbing bout. In addition, providing resting time allows an additional portion of energy expenditure to occur. If resting time is decreased and climbing is resumed before muscles have fully recovered, the exercise begins to add endurance components. Furthermore, lengthening the amount of time an individual spends climbing by doing laps (climbing up to the top and then either down-climbing and immediately climbing back up or being lowered down and then immediately climbing back up repeatedly) can be used to increase endurance effects.

Failed attempts
The physiological responses were similar between the subjects who completed all four climbs and those who did not. This data also fulfilled the ACSM guidelines for energy expenditure and intensity. Therefore, for clarity purposes, the data were pooled. These findings indicate that it is unnecessary to complete a route in order to obtain cardiovascular benefits from rock climbing. Therefore, individuals of all climbing abilities are able to receive cardiovascular benefits from indoor rock climbing.

Duration of exercise

Recorded levels of total energy expenditure and climbing exercise intensity satisfied the ACSM guidelines. However, it is important to note that the amount of time during which the exercise intensity was within the ACSM recommendations was relatively brief when compared to the entire exercise session. In an attempt to remedy this problem, individuals could attempt more than four routes in one exercise session, decrease the amount of rest between climbs, or do laps. These solutions may not be feasible for beginner climbers. In this situation, the lower levels of overall intensity may be seen as a limitation of rock climbing as a suitable alternative exercise.

Limitations and assumptions

There were a few limitations and assumptions in our study. Several times during the study, the portable metabolic analyzer system caused problems in data collection. Some examples of this include, the spirometer cap coming lose while climbing, air escaping from the mask during heavy breathing, the mask getting in the way while climbing, and temporary cease in recording of HR. Our sample was also very specific and homogenous (college-aged and recreational climber) and was selected by means of convenience. The variability of participants' climbing ability may also be considered a limitation. It was assumed that subjects were honest and complied with the directions provided.

Future research

Many variables remain to be study in the field of rock climbing. Some include: differences in physiological response between beginner, intermediate, and advanced climbers; comparing physiological responses before and after treatments comparing the effectiveness of rock climbing versus jogging; investigating/explaining the dissociation between VO_2 and HR evidenced in previous research; determining physiological and health benefits for other populations (overweight, middle class, or youth); and comparing differences in physiological responses of indoor- versus outdoor- rock climbing.

CONCLUSION

Indoor rock climbing is a suitable alternative exercise for college-aged individuals. It meets the ACSM guidelines for %HRR and $\%VO_2R$ recommendations for physical activity and complies with the ACSM and U.S. Surgeon General recommendations for energy expenditure. Individuals who find traditional methods of exercise unexciting will hopefully be inspired to try rock climbing as an alternative form of exercise. Clinicians, strength and conditioning specialists, personal trainers, physical education teachers may use this exciting type of exercise as a way to motivate and encourage exercise adherence in their clientele.

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