Original Research

Health-related Fitness and Energy Expenditure in Recreational Youth Rock Climbers 8-16 Years of Age

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ABSTRACT

International Journal of Exercise Science 8(2): 174-183, 2015. Information on the characteristics of youth rock climbers is minimal. The purpose was to 1) Determine the influence of a three-month program of bouldering and vertical rock climbing on the anthropometry and health-related physical fitness of relatively novice youth climbers, and 2) determine whether rock climbing and bouldering in novice youth climbers can provide adequate levels of moderate to vigourous physical activity (US DHHS, 2008). Fifteen participants (11 males and 4 females; mean age = 11.5 ± 2.3 years) from a newly established youth climbing team were assessed twice weekly during their normal two-hour training sessions at a local rock gym. Body composition, flexibility, grip strength, and anthropometric estimates of somatotype were measured in August and November. Heart rate (HR) monitors recorded average activity heart rate (AHR), peak heart rate (HRpeak), and estimated energy expended (EE-kcals) during each climbing session. Basic descriptive statistics were run; repeat measure ANOVAs were used to assess changes between times. Estimated percent body fat did not change, but individual skinfolds (biceps and supraspinale) decreased significantly ($p<0.05$). Flexibility assessed with the right back-saver sit-and-reach increased significantly ($p<0.05$), but the left back saver did not. AHR ranged between 104-163 bpm, and exercise intensity often reached moderate levels. Overall, the sample had a healthy body composition, a stronger than average grip strength, and an average physique. This activity met recommendations for exercise intensity and duration, and for muscle and bone strengthening. Participating in rock climbing on a regular basis can provide moderate intensity physical activity for youth climbers.

KEY WORDS: Youth rock climbing, energy expenditure, health-related fitness, somatotype

INTRODUCTION

The combined prevalence of children and youth (2-19 years of age) in the United States with a body mass index (BMI) greater than or equal to the 85th percentile (overweight (OW) and obese (OB)) is approximately 32% (19). Of particular concern are higher estimates for minority groups than for Whites (16,19). Specifically, prevalence of OW and OB in Hispanic youth is 39% (19). Though the levels have remained stable for the last few years, the prevalence of OW and OB is too high.

Researchers believe that physical inactivity is a major contributor to this obesity epidemic, given that the prevalence of not meeting physical activity guidelines is approximately 60% in American youth (21, 22, 27). Additionally, low levels of physical fitness have also been shown to be an independent risk factor contributing to morbidity and mortality later in life (4). Minority and lower income youth are often less fit than non-minority and upper socioeconomic status (SES) youth (3,8,9,32). Thus, interventions to increase physical activity among youth, particularly from racial and ethnic minority backgrounds, are necessary.

Rock climbing and bouldering are distinctly different activities compared to the more traditional sports (soccer, baseball, basketball, etc.) or physical activities in which youth usually participate. While it is possible to have a climbing/bouldering team, generally people are involved on an individual basis, albeit with a belayer (i.e., someone holding a secure rope) while climbing. Traditional climbing and sport climbing both involve a climber on the wall and a belayer. When climbing using a top rope, the belayer is on the ground tied into the line the climber is on, making sure if he/she falls, there is minimal risk of injury. Bouldering is a style of rock climbing undertaken without a rope, and is typically practiced on large rocks or artificial boulders. Bouldering emphasizes power, strength, and dynamic moves. Its focus is on individual moves or short sequences of moves. Climbing/bouldering can be done competitively or recreationally; thus the climbers may compete against others or just try to ascend and descend the route successfully.

Perhaps due to the distinctiveness and constant variation of activity involved with climbing/bouldering, youth are taking to this activity in large numbers; approximately 5 million youth younger than 18 years of age climb in rock gyms in the US (20). Thus, climbing /bouldering may be viable options for decreasing OW and OB in youth by keeping them active using a pastime they enjoy. In part because of this enjoyment, youth who prefer to climb/boulder may then continue to exercise in this manner, leading to an increase in overall minutes of activity. As the sport has increased in popularity, it has become more affordable (33). Access to climbing gyms has also become easier in the US, as indoor rock wall gyms have opened up across the country (23). With the availability of rock gyms, the affordable price, as well as the interest shown by youth in this activity, training youth to rock climb safely will allow them more opportunity to climb. Once they have acquired the skill set for climbing, youth have the opportunity to climb/boulder outdoors. Myriad outdoor opportunities for these activities are available, both near major cities and in smaller areas, and outdoor activity has been associated with improvement in overall well-being in adults (6). For youth today, the fact that rock climbing and bouldering have become more accessible and more popular provides good rationale for considering them as viable options to increase physical activity.

In adult climbers, the physiological demands of rock climbing require both aerobic and anaerobic fitness. Metabolically, the cost of climbing can be comparable to moderate-to-vigorous physical activity (MVPA) (25). Climbing/bouldering also increases

muscular strength and endurance and has the potential to increase flexibility in adult climbers (25). However, few studies exist on the impact of rock climbing in youth (i.e., 2, 17).

As researchers, teachers and parents strive to find activities that children and adolescents will perform on a regular basis, with enough duration and intensity to improve fitness, non-traditional activities are becoming more popular and may provide additional benefits. For example, engaging in non-traditional activities may address important psychosocial correlates of physical activity. Self-efficacy and enjoyment of physical education and physical activity are key components linked with physical activity in youth (34). A recent study showed that rock climbing improves self-efficacy in youth 6-12 years of age (14). As part of the drive to develop activities that promote healthy lifestyles and keep youth active, rock climbing/bouldering appear to be a good fit. Although the number of youth who are rock climbing/bouldering is rapidly increasing, very little research exists for the recreational level participant (25). While, some evidence on the physiological demands of competitive elite youth climbing exists (17,25,30), as well as on the anthropometric requirements (31), further research needs to be focused on this area of study. Anecdotally, success at climbing has often been tied to a particular body type (somatotype or physique), but this link has not been empirically determined in recreational youth climbers. Therefore, the purpose of this study was to: 1) determine the influence of a three-month program of bouldering and vertical rock climbing on the anthropometry and health-related physical fitness of relatively novice youth climbers, and 2) determine whether rock climbing and bouldering in novice youth climbers can provide adequate levels (per US DHHS guidelines, 21) of moderate to vigourous physical activity.

METHODS

Participants

Participants included 11 males and 4 females (mean age = 11.5 ± 2.3 years) from a newly established youth climbing team that trained at a rock gym in the inland region of Southern California. The sample included 5 Hispanic, and 10 non-Hispanic participants. All team members were invited to participate in the study; all but three completed the pre and post testing. Participants were all brand new climbers with minimal experience. Baseline measures and a post-program 3-month follow-up were collected on the participants. Participants were also fitted with heart rate monitors twice weekly for 12 weeks. Each training session was approximately 2 hours, and included a short warm up, followed mostly by bouldering for the rest of the time. Bouldering entailed the youth climbers solving bouldering 'problems' or projects on the rock wall. They would work on a project until they could climb the route cleanly, without mistakes. An assent and a consent form were included in the introductory packet of information for the participants to read and sign. The research protocol was approved by the Institutional Review Board (IRB) of California State University, San Bernardino.

Protocol

Baseline and post-study measures for health-related fitness, grip strength, and Heath-Carter somatotype (physique) were

collected on the participants. The Fitnessgram protocol was used to assess health-related fitness variables of muscular strength and endurance, flexibility and body composition (15).

The Fitnessgram® protocol assesses 5 components of health-related fitness. These include: muscular strength, muscular endurance, flexibility, body composition, and cardiorespiratory endurance. Fitnessgram® published cutoffs were used to determine whether the youth climbers were in the Healthy Fitness Zone or not (15). Although not part of the Fitnessgram® protocol, as grip strength is relevant to people who climb and is a well-established indicator of muscular strength, it was also assessed pre and post using a standardized protocol (18). Except for the mile run/walk, all of the fitness assessments were measured in a private room at the climbing gym. Although participants and their parents were asked to arrange a time with the researchers to run/walk the mile at a local school track, too many barriers existed and this never occurred. Transportation was the major problem. Additionally, the closest track was heavily used; when researchers attempted to reserve times for use, it was not possible, and there were multiple individuals/teams using the track itself and surrounding fields. Thus, the cardiorespiratory component of the Fitnessgram® protocol was not completed for this study.

For all health-related fitness items, participants were shown how to perform the activity, and then they were allowed to practice it enough for it to become familiar and for researchers to make sure that they were using proper technique. Unless otherwise stated, one trial was performed and recorded.

Push-ups: Participants were asked to complete as many push-ups as possible at a rhythmic pace, the cadence was set at 20 push-ups per minute (1 every 3 sec). Males and females were asked to use their toes as the pivot point, not their knees.

Curl-ups: Participants were asked to complete as many curl-ups as possible up to a maximum of 75 at a specified pace. For this protocol, participants lay supine with knees bent, and the hands slide toward the feet on the ground.

Grip strength: After the dynamometer (Takei, Japan) was set to the appropriate distance for each participant's grip (middle joint at 90 degrees), participants were asked to squeeze the hand-grip as hard as possible. Participants were told to stand for this activity. The grip strength results were presented as the best of both left and right grip after three trials, as well as the sum of the largest readings from each hand. The results were compared to recommended guidelines (18).

Flexibility: For the Back Saver Sit and Reach, participants were told to remove their shoes and sit down in front of the sit and reach box. One leg was fully extended with foot flat against the box; the other knee was bent with sole of the foot flat on the floor, two inches to the side of the straight leg. Arms were extended forward over the scale with hands placed on top of each other. With their palms facing down, participants were told to reach forward and hold the position for at least one second. The best of three trials was recorded for each side.

Skinfold: Triceps, biceps, medial calf, subscapula, suprailiac, suprapinale, and thigh skinfolds were measured using standardized protocols (12). Thus, two measures were taken and averaged, unless they were more than a millimeter (mm) apart, then a third skinfold was taken, and all three averaged. The same trained individual was responsible for all skinfold measures, both pre and post. The skinfold measurements were then entered into Lohman's (12) youth-specific formulae and percent fat calculated. In addition, BMI was calculated from weight (kg)*height (m^{-2}).

Circumferences: Waist and hip circumferences, relaxed and flexed arm, and calf circumferences were measured. The circumferences were measured twice, and measures were averaged.

Skeletal breadths: Skeletal breadths give researchers an indication of the robusticity of the skeletal frame of the participant. Four breadths were measured: biepicondylar, bicondylar, biacromial, and bicristal. All breadths were measured twice and averaged if they differed.

Somatotype: In addition to providing a general physical description of the study sample, stature, weight, biepicondylar and bicondylar breadths, flexed arm and calf circumferences, and triceps, subscapular, supraspinale and medial calf skinfolds also allowed for a calculation of Heath-Carter somatotype (7). Somatotype (physique) was calculated using measurements described above, providing a means to assess the body structure -- endomorphy (relative fatness), mesomorphy (relative muscularity), and ectomorphy (relative linearity) -- of individuals. The higher one's score in any category, the higher the expression of that component of somatotype (7).

Estimates of energy expenditure (EE) and heart rate: Heart rate (HR) monitors (Polar, Inc.) were placed on participants at the beginning of each climbing session; HR was downloaded after every activity bout. Average activity heart rate (AHR), peak heart rate (HRpeak), duration of activity, and estimated energy expended (total kcals and kcals/min) were recorded from the HR monitors.

Statistical Analysis

Basic descriptive statistics were run. Repeated measures ANOVA was used to determine whether health-related fitness characteristics differed over the course of the study. The IBM Statistical Program for Social Sciences (SPSS) version 18.0 was used for all analyses, significance level was set at 0.05.

Table 1. Descriptive statistics for select baseline variables.

Age (yrs)	11.5 ± 2.3
Height (cm)	144.5 ± 12.2
Weight (kg)	39.3 ± 11.7
BMI (kg/m^2)	18.5 ± 3.6
Endomorphy	3.9 ± 1.7
Mesomorphy	4.2 ± 1.1
Ectomorphy	3.0 ± 1.4

RESULTS

Means and standard deviations for select baseline measures are presented in Table 1. The mean BMI for the total sample was 18.5 ± 3.6 kg/m^2 at the start of the study; the majority of the participants were considered normal weight by Centers for Disease Control and Prevention cutoffs (5).

Only one participant was in the Overweight (OW) category. On average, the sample had a healthy body composition, was of normal weight, and had an average grip strength (18). In addition, the sample was average in physique; somatotype was in the range of 3-3-3 to 4-4-4, or located in the middle of the somatochart (See Figure 1). However, the sample was slightly more mesomorphic (muscular in build) than either endomorphic (predominance of fat) or ectomorphic (linear in build). Somatotype is plotted on the somatochart in Figure 1.

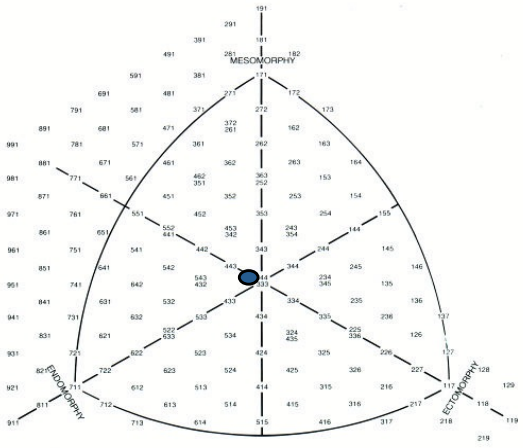

Figure 1. Mean somatotype for sample.

Due to the participants increasing in age from pre to post, they were significantly taller at the end of the study ($F_{(1,12)}$ = 6.49, p< 0.05). In addition, the biepicondylar (elbow) breadth significantly increased between pre and post test ($F_{(1,12)}$ = 7.60, p< 0.05), likely for the same reason.

Estimated percent body fat did not change over the three months of the study, but individual skinfolds (biceps and supraspinale) decreased significantly (p<0.05) (Table 2). Although a decrease in endomorphy (relative fatness) was noted, it was not significant (p = 0.09). Flexibility assessed with the right back saver sit-and-reach increased significantly ($F_{(1,12)}$ = 4.93, p< 0.05), but the left back saver sit and reach did not (p>0.05).

Table 2. Pre and post-test results for select health-related fitness items.

Variable	Baseline M ± SD	Post M ± SD
BMI (kg/m^2)	18.5 ± 3.6	18.7 ± 3.8
Body Fat (%)	18.5 ± 6.6	17.0 ± 4.4
Pushups (#)	18.0 ± 13.0	15.0 ± 10.0
Sit-ups (#)	24.0 ± 17.0	28.0 ± 16.0
Right sit and reach (cm)	28.1 ± 4.4	29.6 ± 4.1*
Left sit and reach (cm)	28.9 ± 4.2	29.7 ± 4.3
Biceps Skinfold (mm)	9.1 ± 5.6	7.8 ± 4.7*
Supraspinale Skinfold (mm)	10.4 ± 6.6	8.4 ± 5.2*

Both exercise time and energy expenditure approached recommended guidelines for youth physical activity (Table 3). AHR in the youth climbers ranged from 104-163 bpm, and the exercise intensity reached moderate to vigorous levels according to US DHHS guidelines (21). Although the overall for AHR for all the bouts in this study was 132.6 ± 9.1bpm, many of the youth climbers had average heart rates above 140 bpm for the majority of the time they trained.

Table 3. Descriptive statistics for heart rate and estimated energy expenditure.

Average Heart Rate (bpm)	132.6 ± 9.1
Peak Heart Rate (bpm)	187.6 ± 12.4
Total energy expenditure (kcals)	599.0 ± 227
Average energy expenditure (kcals/min)	5.7 ± 1.7
Average time (min)	105.8 ± 25.2

DISCUSSION

Overall, this sample of youth climbers did not change in most physical measures (anthropometry, health-related fitness

parameters) over the 3 months of the study. Due to the natural aging process, participants did get physically bigger, but the majority of the measures did not differ significantly. The general trend across the three-month program indicated improvement in most dimensions of health-related fitness items, although the small sample size influenced the statistical significance of the observed changes.

The current climbing study was 12-weeks long; a longer time period to assess possible changes in anthropometry and health-related fitness would be beneficial. Other work has shown that after-school PA programs conducted over two years were more efficacious in increasing long-term PA than those lasting only a year (13, 26). Additionally, the likelihood of youth remaining active over time was directly related to how long they stayed in the after school PA programs (13). In the current study, the frequency, intensity and duration of climbing was likely not of a sufficient level to induce overall health-related fitness changes. However, as youth become more experienced at climbing, it seems likely they will climb longer, more intensely, and more frequently.

The 2008 Physical Activity Guidelines for Americans recommend that children and adolescents participate in at least 60 minutes of MVPA most days of the week, preferably daily, in order to attain health benefits (21). MVPA is defined as ≥ 4 METs, or a heart rate approximating 140-160 bpm (1, 26, 28). In terms of meeting these guidelines, few studies have addressed this component in youth climbers; most of the comparison studies in rock climbers, therefore, are based on results from adults. One investigation involving adult recreational climbers found that rock climbing provided adequate aerobic intensity to maintain good cardiorespiratory fitness according to American College of Sports Medicine (ACSM) guidelines (24). Also for adults, exercise intensity (VO_2 during rock climbing expressed as a percentage of VO_2 peak) ranged from 70 ± 6% to 72 ± 8% of VO_2peak (maximal aerobic capacity) for males and females, respectively (24). Although males and females were grouped together in the current study of youth climbers, the average estimated exercise intensity (assessed via heart rate monitors) was 70 ± 2% of estimated VO_2peak. Not all youth in the current study reached the level of moderate PA at all times. However, many of the youth climbers exercised at a moderate level for the majority of the time they trained. For those who did not reach moderate levels, it could be related to skill and confidence, as well as fitness and motivation for PA.

In comparison to the work by Trost et al. (28), the estimated EE of participants in the current study (~6 METs) ranged between walking on a treadmill (5.2 ± 0.9 METs), and actively shooting and retrieving a basketball (7.2 ± 1.6 METs). Similarly, the estimated activity of climbers from the current study ranged between dancing and bicycling (5 METs) and Running/Basketball/Football/Soccer (all at 8 Mets) (10). Thus, participation in rock climbing has the potential to provide sufficient levels and adequate intensity of PA to meet US DHHS recommendations (21).

Based on the results from this study, participating in rock climbing on a regular basis can result in improvement in some components of health-related fitness in

youth climbers. In addition, participating in rock climbing can provide moderate intensity physical activity for youth climbers. Although it was not part of the purpose of the study to investigate racial/ethnic differences, and true comparisons were not possible due to sample size constraints, it is important to note that one-third of the current sample was Hispanic. The fact that racial/ethnic minorities were interested in participating in this activity, and experienced benefits similar to those of their non-Hispanic peers, indicates that climbing and bouldering may also be attractive to this at-risk population.

Although flexibility improved slightly as assessed with the right back saver sit and reach, no significant differences were found between pre and post muscular strength and endurance assessments. Nevertheless, participants reported feeling stronger and more confident in their climbing by the end of the study. In addition, participants were climbing better, and making better decisions on their routes (per input from group instructors and climbing coaches).

Generally, youth rock climbing and bouldering in this pilot study approached US DHHS recommendations for moderate to vigorous cardiorespiratory activity (≥ 4 METs) (21). In addition, rock climbing and bouldering can provide much needed muscle- and bone- strengthening activity, also aligning with the guidelines for physical activity in youth (21). Based on the results from this study, participating in climbing on a regular basis has the potential to increase to recommended levels the intensity, frequency, and duration of this activity in youth climbers (21).

Further study needs to be performed on many aspects of this work. The feasibility and sustainability of a rock climbing/bouldering program is an issue that should be addressed. Although climbing/bouldering appears to be beneficial to youth, these activities have been perceived as expensive. In particular, given the need for low SES and minority youth to increase activity levels, this perception needs to be assessed. The proliferation of indoor climbing gyms and walls has made the activity more accessible, making it more likely that parents can utilize this activity for their children.

Lastly, an intervention study designed to specifically assess the quantity and quality of rock climbing as an activity choice for low-fit youth needs to be explored. Youth who like to rock climb and boulder appear to have high exercise adherence (personal observation), but future work needs to specifically address this question. In addition, while research shows that body composition impacts the performance at higher levels of the sport (31), it does not seem to have as much influence in each participant's enjoyment of the sport at recreational or less elite levels (personal observation). Thus, by assessing climbing in more youth, including children who are overweight, researchers, teachers, and parents can present climbing/bouldering as yet another viable option for improving body composition in children and youth by keeping them active, using a pastime they enjoy.

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