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Prusik Climbing to Promote Moderate to Vigorous Physical Activity for Youths

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The purpose of this study was to examine mean heart rate (HR) responses of youths in prusik climbing, compared to indoor rock climbing. Twenty eight college students (18-25 yrs.) were randomized into Group 1 (n = 14) and Group 2 (n = 14). During the walk (15-minunte) and exercise bouts (15-minute) of each participant, HR was measured using a Polar Advantage XL Heart Rate monitor and was recorded every 5 seconds and averaged into 5-minute intervals. A three-way repeated measures analysis of variance (ANOVA) revealed that indoor rock climbing had a significantly higher mean HR ($F = 9.153$, $df_1 = 1$, $df_2 = 26$, $P < 0.05$) than prusik climbing, but both mean HRs at each time interval were in the moderate to vigorous range. Prusik climbing may be an effective alternative over indoor rock climbing in physical education settings to promote students' moderate to vigorous physical activity at minimal cost and space.

Key words: lifetime activities, adventure education, climbing, MVPA, youths

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There have been substantial changes in physical education standards and grade level outcomes to better plan and utilize best practice in physical education, but also to help students develop lifetime physical activity habits (SHAPE America, 2013). One of the substantial changes is a focus on health-enhancing lifetime physical activities, particularly when children move into adolescence as their physical activity levels dramatically decreased. For example, one third of high school grade-level specific outcomes for standard 1 (i.e., demonstrates competency in a variety of motor skills and movement patterns) solely consists of lifetime activities, such as outdoor pursuits. Rock climbing (both indoor and outdoor) may be one of the most common activity forms teachers plan and implement as outdoor pursuits in a lifetime physical activity unit as it becomes popular (Larew & Haibach-Beach, 2017). For instance, IBIS World (2014) reported 627 indoor climbing gyms were open in the United States with many hosting competitive age groups ranging from 11 & under through adults; rock climbing (both indoor and outdoor) may be one of the most common activity forms teachers plan and implement as outdoor pursuits in a lifetime physical activity unit. A plenty of research shows that climbing activities produce adequate energy expenditure (EE) to attain health benefits.

According to Compendium of Physical Activities (Ainsworth, 2011), slow to moderate rock climbing is rated at 5.8 metabolic equivalent of task (MET), high difficulty rock climbing at 7.5 METs, and rock or mountain climbing rated at 8 METs. A meta-analysis of Li et al. (2018) found rock climbing significantly increases oxygen consumption (VO_2) for college students. For students desiring a vigorous workout that adds a mental challenge, rock climbing slow or fast gives them a vigorous bout of exercise. Sanders (1999) found an increase in heart rates (HR), VO_2, and caloric expenditure as the difficulty of the climbing route increased. Also, Betuzzi, Franchinni, Kokubum, and Kiss (2007) showed HR to be higher in recreational rock climbers compared to elite climbers. This finding indicates that those with less rock climbing experience (e.g., students in physical education) can experience a more demanding work out when climbing the same routes as someone with more experience due to the lack of efficiency in novice climbers. This idea may apply to many high school and college students who may have a lack of climbing experience; as a result, climbing activity can be a good means to promote moderate to vigorous physical activity (MVPA) as well as muscular strength in youths.

Watts and Ostowski (2014) measured VO_2 and EE of children (9-11 years old) who completed 5 minutes of continuous rock climbing, in the form of bouldering, and a 10 minute interval rock climbing, in the form of bouldering, of 1 minute of climbing with one minute of rest. It was found that children experienced a higher VO_2 and EE after completing 5 minutes of continuous rock climbing compared to 10 minutes of interval climbing. Evel (2000) tested heart rates of middle school aged

students with and without an intellectual disability in high ropes course activities. While there was no significant difference of heart rate between the two groups, the students with an intellectual disability had a mean heart rate of 158 beats per minute (bpm); students without an intellectual disability had a mean heart rate of 170.5 bpm. Despite the effectiveness of indoor and outdoor climbing activities, some physical educators may have challenges in using climbing activities due to lack of funding, space and resources in their schools and districts. Prusik climbing may be a promising alternative for physical educators facing those challenges.

The prusik knot, also known as the prusik hitch, was used in single rope climbing during the 20th century through the 1990's by mountaineers, rappelers and arborists (Adams, 2005). Single rope ascents using a prusik knot came to be known as prusik climbing and became popular in the mountaineering and climbing community (Long, 2007). Prusik climbing requires the use of the arms and legs to manipulate the two prusik knots attached to a single rope. One prusik knot is attached from the rope to the harness of the climber while the second prusik knot is used as a foot loop for climbers to use their legs during the ascent. Prusik climbing requires the coordination of the arms and legs unlike indoor rock climbing where participants can rely on their upper body or lower body to do the majority of the EE. Sell, Clocksin, Spierer, and Ghigiarell (2011) studied adults participating non-traditional activities, including 30 minutes of prusik climbing, and found prusik climbing had significantly higher, EE, VO_2 , HR, RPE compared to walking, Wii boxing, and stepping.

Despite the potential benefits, there is very limited research evidence on the EE of prusik climbing compared to indoor climbing while Adams (2005) dated the earliest mention of the French Prusik hitch to 1944. Therefore, the purpose of the current study was to examine mean HR response of youths in prusik climbing in comparison with indoor rock climbing. The following questions were examined to achieve the study purpose: (1) Is there a significant difference in HR when comparing prusik climbing and rock climbing at different time points? (2) Does gender moderate the relationship between different types of climbing and HRs? and (3) Is there an interaction effect between time and walking on climbing HRs?

Methods

Participants

A convenience sample of 28 college students (age range 18-25; 12 males and 16 females) enrolled in a freshmen-level physical activity courses at a public university in Midwest, USA, participated in this study. These college students were selected in this study because of its convenience sampling

nature under an assumption that the development of youths and upper classmen in high school are similar. A total of 35 college students were initially recruited, but seven of them could not participate due to time constraints. Descriptive information of 28 study participants is shown in Table 1. All participants had minimal prusik climbing experience (i.e., having prusik climbed less than two times in their life). Written informed consent was obtained prior to beginning of the study. Approval from the University Institutional Review Board for the Protection of Human Subjects was obtained prior to data collection.

Table 1. *Physical characteristics of participants*

	Group 1	Group 2
Age (years)	20.6 + 1.4	20.3 + 2.3
Height (cm)	172.0 + 10.6	172.3 + 10.0
Weight (kg)	72.9 + 10.8	73.0 + 16.6
Females	n = 7	n = 9
Males	n = 7	n = 5

Instruments

Participants were screened for physical activity readiness by using the Physical Activity Readiness Questionnaire (PAR-Q). This questionnaire was used to assess a participant's ability to do physical activity. Failing the PAR-Q resulted in elimination from the study. To objectively measure study participants' heart rates, Polar Advantage XL Heart Rate monitors (Polar Electro Incorporated, Lake Success, NY) were used. Previous studies (Goodie, Larkin, & Schauss, 2000; Terbizan, Dolezal, & Albano, 2002) demonstrated validity and reliability of the heart rate motors in youths. Participants wore a transmitter fastened to their chest with an elastic band and a wrist-watch monitor.

Protocols

Order of testing protocols was randomized prior to testing and participants were divided into two groups as described in Table 1. Prior to any testing, participants were asked to refrain from moderate to vigorous physical activity 24 hours prior to testing; participants were asked to not eat, smoke, or drink anything (except water) 3 hours prior to testing to increase optimal performance. Height, weight (without shoes), and age was recorded before testing began and after completion of the informed consent and PAR-Q. Participants were randomized using a random number generator for order of exercise bouts and were labeled as Group 1 or Group 2. The participants completed two exercise

bouts on two separate days no less than 24 hours and no more than one week between bouts.

On the first day of testing, Group 1 completed a 15-minute self-paced walk. Heart rate (HR) was recorded at 5-second intervals and was later averaged into 5-minute intervals. After the completion of the 15-minute self-paced walk, participants in Group 1 completed a 15-minute self-paced 33-foot 5.6 Yosemite Decimal Scale indoor rock climbing route using the True Blue Auto Belay System (Head Rush Technologies, Boulder, CO). Time was announced at the 5-minute, 10-minute, 13-minute, and 15-minute marks. HR was recorded at 5-second intervals and was later averaged into 5-minute intervals. On the second day of testing, Group 1 completed a 15-minute self-paced walk. HR was recorded at 5-second intervals and was later averaged into 5-minute intervals. After the completion of the 15-minute self-paced walk, participants in Group 1 completed a 15-minute self-paced 33-foot prusik ascent and were lowered to the ground at the completion of each ascent by a trained belayer. Time was announced at the 5-minute, 10-minute, 13-minute, and 15-minute marks. HR was recorded at 5-second intervals and was later averaged into 5-minute intervals. Group 2 completed the same testing protocols as Group 1 with the difference of Group 2 completed the prusik climb on the first day of testing and completed the indoor rock climb on the second day of testing.

Analysis

A three-way repeated measures analysis of variance (ANOVA) was used to compare the HR on the types of climbing (i.e., rock climb vs. prusik climb), gender and different time points (i.e., 5-10-15 minute internals), and the mean HR of walking exercise bout before indoor rock climbing, and the mean HR of walking exercise bout before prusik climbing. During the three-way ANOVA, interaction terms were analyzed to see the gender effect. A one-way ANOVA was used to compare only the 1st minute of HRs between indoor rock climbing and prusik climbing. In addition, a two-way repeated measures ANOVA along with interaction terms was used to test the interaction effect of time and pre-walking on climbing HRs where dependent variable was mean climbing HRs and independent variables were time and the activity (indoor rock climbing or prusik climbing). When analyzing indoor rock climbing, the Greenhouse-Geisser adjustment was used because the data did not satisfy the Sphericity test (i.e., unequal group variance). Alpha was set at 5% for all analyses.

Results

It was found that the mean indoor rock climbing HR was significantly higher than prusik climbing HR, $F(1, 26) = 9.153$, $p < 0.05$. Nevertheless, mean HRs of both indoor rock climbing (171.83 bpm) and prusik climbing (167.73 bpm) were in the MVPA range (moderate > 139 bpm & vigorous >159

bpm; Wang, Pereira, & Mota, 2004). Table 2 and Figure 1 show specific mean HR differences at each time interval for rock climbing and prusik climbing. ANOVA showed no significant difference in mean HR when comparing only the first minute of HR between rock climbing and prusik climbing and demonstrated the walks before the exercise bout were consistent. The mean HR for the first minute and subsequent minutes can be seen in Figure 2.

Table 2. *Mean HR (bpm) for rock climbing and prusik climbing over the 15-minute exercise bout*

	Mean HR	Lower Bound HR	Upper Bound HR
Rock climbing	171. 83	165.25	178.41
Prusik climbing	167.73	158.55	170.91

Note. bpm =beats per minutes

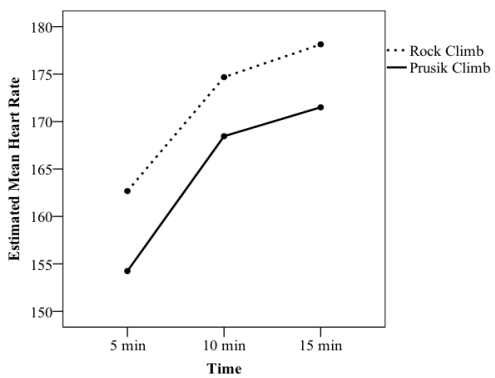

Figure 1. *Mean HR displayed at 5-minute interval over a 15-minute exercise bout*

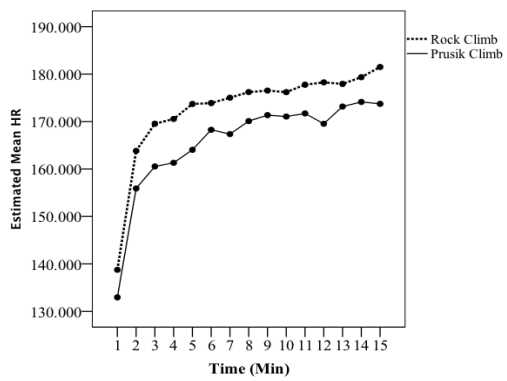

Figure 2. *Average HR for each minute for indoor rock climbing and prusik climbing*

A three-way repeated measures ANOVA revealed that the difference in HR between gender was not statistically significant nor was gender involved in any significant interaction effects. Based on a two-way repeated measures ANOVA, a significant interaction effect was found when comparing time's effect on mean HR in walking and indoor rock climbing over time using the Greenhouse-Geisser adjustment for sphericity, F (1.134, 27.207) = 7.018, $p < 0.05$. This finding demonstrated, for healthy college students, the differences in average HR were significantly different over the 5-minute, 10-minute, and 15-minute intervals when comparing indoor rock climbing to walking. The HR when climbing was always greater than when walking and the difference increased as time went on can be seen in Figure 3. In addition, there was a significant interaction effect on mean HR when comparing

prusik climbing HR to pre-prusik climb walking HR, F (1) = 323.618, p <.001. When taking time into account, a significant difference in HR was found, F (2, 52) = 21.360, p < 0.05. This is the same basic pattern exhibited in the comparison between the rock climbing and the walking. The HR averages displayed in 5-minute intervals for prusik climbing HR to pre-prusik climb Walking HR is shown in Figure 4.

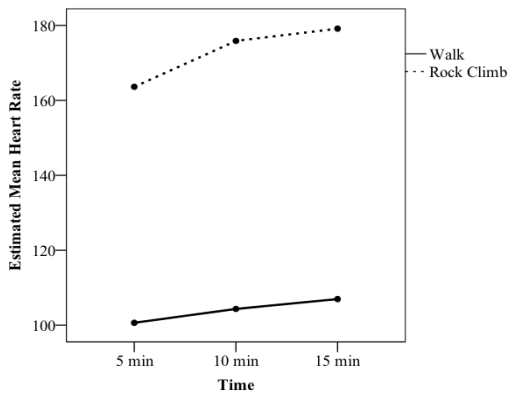

Figure 3. *Mean HR displayed in 5-minute intervals over the 15-minute exercise bout*

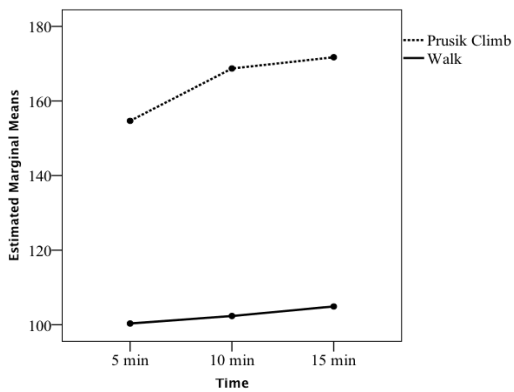

Figure 4. *HR of walk before prusik climb compared to HR during prusik climbing*

Discussion

The purpose of this study was to compare the difference in HR responses between indoor rock climbing and prusik climbing. While there was no significant difference in HR between the first minute of indoor rock climbing and the first minute of prusik climbing, a significant difference in HR was found when comparing the intervals of time (5-minute, 10-minute, and 15-minute) against each other. There was also a significant difference in HR when comparing the 5-minute, 10-minute, and 15-minute time intervals in indoor rock climbing compared to prusik climbing. Average HR increased during each time interval in indoor rock climbing and prusik climbing, with HR being higher in indoor rock climbing compared to prusik climbing.

Using the HR guidelines for moderate physical activity (MPA) and vigorous physical activity (VPA) (Wang et al., 2004), all HR time intervals were within MPA and VPA, meaning indoor rock climbing and prusik climbing can be categorized as activities that result in MVPA. In support of this finding, Sell et al. (2011) found prusik climbing to average 6.5 METs by measuring VO_2, HR, rate of perceived exertion (RPE), and respiratory exchange ratio (RER). With an average of 6.5 METs,

prusik climbing with average HR rate of 167.73 was within the MVPA range (Center for Disease Control and Prevention, 2011), as a result, this finding indicates that prusik climbing can be used as activity to promote MVPA.

Several researchers investigated MVPA and EE in adventure based physical education classes. Gehris Myers and Whitaker (2012) found 40% of class time was spent in MVPA when time was spent in high elements and initiatives compared to 28.3% of the time in MVPA when progressing through the other stages of adventure. Watts et al. (1999) found average EE to be equivalent to 4 METs when participants were crossing the first balance beam and step swing with peak EE to be equivalent to 6-7 METs when completing the second balance beam and swinging tires in a 5-element sequence of an indoor ropes course. Evel (2000) had tested middle school aged students with and without cognitive disabilities and found students mean HR to be within the MVPA range (158-170.5 BPM) when climbing. The addition of prusik climbing to high elements and initiatives may increase the amount of time students spend in MVPA when engaging in adventure based activities in high school physical education because the waiting time is minimized when many prusik ropes are available.

The decision to use one route with no access to this route during the indoor rock climbing class is supported by the findings of España-Romero, Jensen, Sanchez, Ostrowski, Szekely, and Watts (2012) that revealed a decreased HR as a route becomes familiar. In this study participants were able to see the holds available on the route and they were not allowed to climb the route until it was their day to test the continuous indoor rock climb. This limited the potential decrease of HR due to familiarity of the route.

A limitation of this study was the inability to compare the number of ascents completed within the 15-minute time frame and its effect on mean HR. Given the self-paced premise of the study, those participants who wanted to achieve the most ascents in the given time frame may have had different mean HR than those who completed fewer ascents. A second limitation of the study was the use of an indoor rock climbing class. Lopera, Porcari, Steffen, Doberstein, and Foster (2011) found participants engaged in a 7-week rock climbing program gained muscular strength and endurance. Because testing was spread out over the course of a semsester, students enrolled the rock climbing class may have gained muscular strength and endurance, which could have an effect on mean HR and the number of ascents a participants could complete. A third limitation to the study was the potential effects of anxiety on HR. Draper, Dickson, Fryer, Blackwell, Winter, and Scarrott (2012) found an increase of self-confidence decreased cortisol levels. In rappelling it was found that heart rate, state anxiety, and electromyography was higher in participants who were not trained in rappelling (Brody, Hatfield, & Spalding, 1988). While participants in the current study were trained in belay

techniques for indoor rock climbing, none were pre-trained in the use of the True Blue Auto Belay System (Head Rush Technologies, Boulder, CO) or prusik climbing.

In conclusion, this study shows that prusik climbing is an effective alternative for secondary level physical educators who may have limited resources for indoor climbing (e.g., space and funding) because both indoor rock climbing and prusik climbing HRs fall into a range of MVPA. It is hoped that many physical education teachers include prusik climbing in their physical education curriculum (e.g., fitness and physical activity enhancing activity) as a means to implement standard-based practice (e.g., SHAPE standards and grade level outcomes) and eventually foster lifelong activity for high school students.

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