UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

AN ANALYSIS OF THE EFFECT OF PRUSIK CLIMBING AND INDOOR ROCK CLIMBING ON HEART RATES

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Exercise and Sport Science

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College of Science and Health
Physical Education Teaching

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AN ANALYSIS OF THE EFFECT OF PRUSIK CLIMBING AND INDOOR ROCK CLIMBING ON HEART RATES

By Nathali Niedorowski

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Exercise and Sport Science with emphases in Physical Education Teaching with emphasis in Adventure Education.

The candidate has completed the oral defense of the thesis.

Jeffrey Steffen, Ph.D. Thesis Committee Chairperson	5/8/15 Date
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Thesis accepted

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ABSTRACT

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This study was designed to compare mean heart rate (HR) responses in prusik climbing and indoor rock climbing. Twenty-eight college-aged participants (18-25 yrs.) were randomized into Group 1 (n = 14) and Group 2 (n = 14). Each participant completed a 15-minute walk prior to a 15-minute exercise bout. Group 1 completed an indoor rock climbing exercise bout on day 1 of testing and prusik climbing exercise bout on day 2 of testing. Group 2 completed the exercise bouts in reverse order. During the walk and exercise bouts HR was recorded every 5 seconds and averaged into 5-minute intervals. No interaction (gender x climb x time) was noted for mean HR. Significant interaction (mean HR of walk x mean HR of indoor rock climbing x time) ($P < 0.05$) and (mean HR of walk X mean HR of prusik climb x time) ($P < 0.05$) was found. No significant difference was found in mean HR for the first minute of prusik climbing compared to indoor rock climbing. A significant difference was found in mean HR in prusik climbing compared to indoor rock climbing over a 15-minute period ($P < 0.05$).

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INTRODUCTION

As the ability for increase science's ability to document physiological changes to the human body as a result of physical activity, the amount and variety of physical activities have also increased with non-traditional activities being just as effect as traditional activities ("USC Prevention Research Center: PRC Reports and Tools", 2003). Some examples of non-traditional physical activities included in the Compendium of Physical Activities (2003) and General Physical Activities Defined by Level of Intensity CDC, 2011) are rock climbing, rappelling, judo, and unicycling. Both documents have the activities organized by metabolic equivalents (METs), which is one way to chart the physiological changes. Wang, Pereira, and Mota (2004) identified moderate physical activity (MPA) as a heart rate (HR) of 139 – 159 beats per minute (BPM), or 3-6 METs and vigorous physical activity (VPA) as a HR of 159 or more BPM, or 6 or more METs.

A non-traditional activity that has been receiving scientific evaluation through the form of evaluating HR and energy expenditure (EE) is indoor and outdoor rock climbing. It has been found that climbing routes of varying difficulty has positive correlation on HR (Mermier, Robergs, McMinn, & Heyward, 1997). Using the Compendium of Physical Activities (2003), as a MET guideline, slow rock climbing is rated at 8 METs, general rock climbing was rated at 10 METs, and fast rock climbing was rated at 12 METs. For people desiring a vigorous workout that adds mental challenge to the physical challenge rock climbing slowly or fast give the participants a vigorous bout of exercise. Sanders (1999) found an increase in HR, oxygen consumption

(VO_2), and caloric expenditure as the difficulty of the climbing route increased. Betuzzi, Franchinni, Kokubum, and Kiss (2007) found HR to be higher in recreational rock climbers compared to elite climbers. Using Betuzzi et al. research, those with less rock climbing experience 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. Watts and Ostowski (2014) measured VO2 and EE of children who completed 5 minutes of continuous rock climbing and a 10 minute interval rock climb 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 (Watts, 2000). Watts' article can be used as a guidance for physical educators looking to use bouldering as a tool to increase EE in students. A second activity that could be used for physical activity for adults and in a physical education setting is prusik climbing.

The prusik knot was used in single rope climbing during the 20th century through the 1990's (Adams, 2005). Single rope ascents using a prusik knot came to be known as prusik climbing and the term prusik climbing became popular in the mountaineering and climbing community (Long, 2007). Sell, Clocksin, Spierer, and Ghigiarell (2011) published a study of adults participating non-traditional activities, including 30 minutes of prusik climbing. While Adams (2005) dated the earliest mention of the French Prusik hitch to 1944, there is limited information on the energy expenditure of prusik climbing

To gain a better understanding of a prusik climber's HR, this study was designed, The purpose of the current study was to compare the difference in HR responses between indoor rock climbing and prusik climbing. Prusik climbing requires the use of the arms and legs to manipulate the prusik knots while ascending the rope where participants can rely on their upper body or lower body to do the majority of the EE in indoor rock climbing. The following questions were purpose to assess the difference in HR: 1. Does gender have a correlation to HR? 2. Is there a correlation between time, physical activity, and HR? 3. Is there a significant difference in HR at the beginning of the prusik climb compared to the HR at the beginning of the indoor rock climb? 4. Is there a significant difference in HR when comparing time, prusik climbing, and rock climbing?

METHODS

Participants

A convenience sample of 35 college students enrolled in 100 level physical activity classes were recruited for this study. 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 the study. Approval from the University Institutional Review Board for the Protection of Human Subjects was obtained prior to the beginning of this study. Order of testing protocols were randomized prior to testing and participants were divided into two groups. Descriptive information of study participants in group 1 (n = 7 females and n = 7males) and study participants in group 2 (n = 9 females and n = 5males) is shown in Table 1.

Table 1. Descriptive characteristics of subjects

Variable	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 wore a Polar Advantage XL Heart Rate monitor (Polar Electro Incorporated, Lake Success, NY) fastened to their chest with an elastic band and a wrist watch monitor. Participants were screened for physical activity readiness by using the Physical Activity Readiness Questionnaire (PAR-Q). This questionnaire is used to assess a participants ability to participate in physical activity. Failing the PAR-Q results in elimination from the study.

Protocols

A total of 28 of the 35 participants completed the study protocol. Seven could not participate due to time constraints. Order of testing protocols was randomized prior to testing and participants were divided into two groups. 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 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 subjects then 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 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

The purpose of this study comparing mean HR for the rock climb versus the prusik climb over time for males and females were tested using a three-way repeated measures analysis of variance. Comparisons were made between mean HR of indoor rock climbing, mean HR of prusik climbing, mean HR of walking before indoor rock climbing, mean HR of walking before prusik climbing, over the 15-minute time period.

RESULTS

Twenty-eight of the original thirty-five recruited completed the study protocol. Time constraints and the failure of the PAR-Q resulted in 7 subjects unable to complete the study.

1. Does gender affect mean HR? A three-way repeated measures analysis of variance (ANOVA) was used to compare the effects of the type of climb on mean heart rate in addition to the effects time and gender at a 5% level of significance. It was found that the difference in heart rate between genders was not statistically significant (F = 0.064, $df_1 = 1$, $df_2 = 26$, $P = 0.802$). Nor was gender involved in any significant interaction effects.

2. Is there a relationship between time, physical activity, and HR? A two-way repeated measures ANOVA was used to compare the average rock climbing HR to Pre-Rock Climb Walking HR. Because the data failed the sphericity test, the Greenhouse-Geisser adjustment was used.

A significant interaction effect was found when comparing time's effect on mean HR in walking and indoor rock climbing over time ($F = 7.018$, $df_1 = 1.134$, $df_2 = 27.207$, $P < 0.05$). This means, for healthy college aged individuals, the differences in average HR were significantly different over the 5-minute, 10-minute, and 15-minute interval when comparing indoor rock climbing to walking. The HR when climbing was always greater than when walking and the difference increase as time went on can be seen in Figure 1.

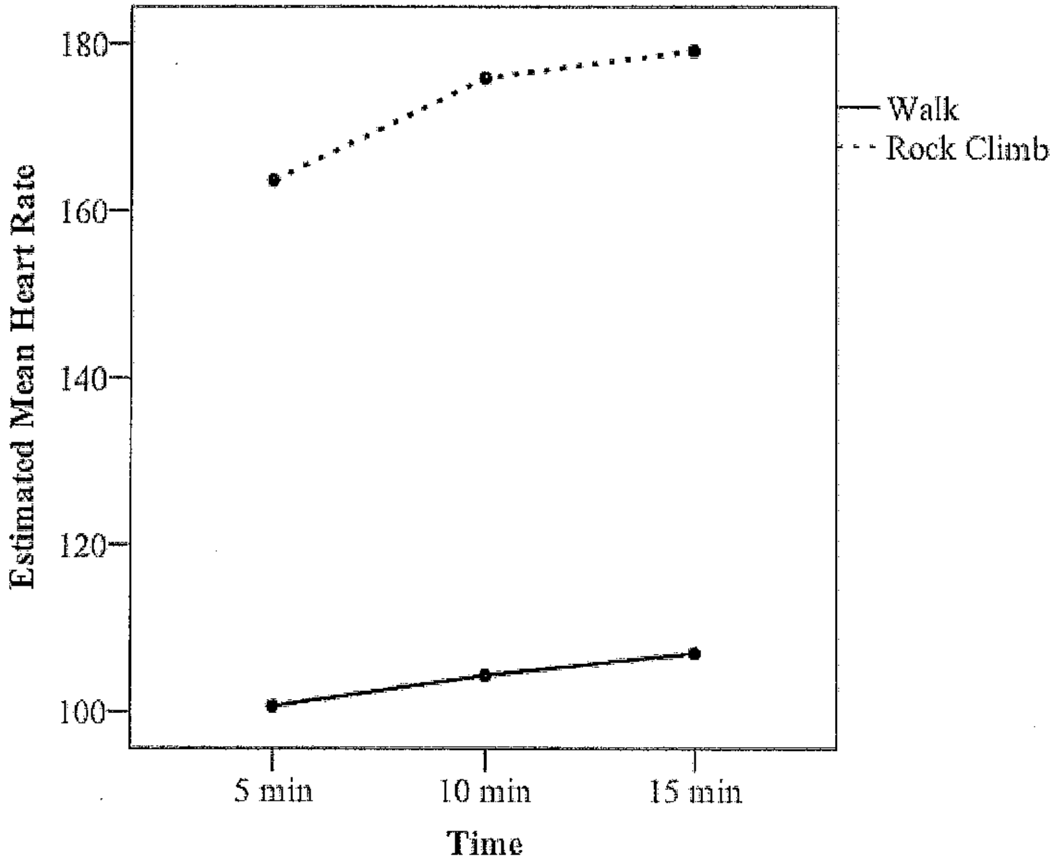

Figure 1. Mean HR displayed in 5-minute intervals over the 15-minute exercise bout.

When comparing prusik climbing HR to pre-prusik climb walking HR through a two-way repeated measures ANOVA, a significant interaction effect on mean HR was found ($F = 323.618$, $df_1 = 1$, $P = 0.000$). When taking time into account, a significant different in HR was found ($F = 21.360$, $df_1 = 2$, $df_2 = 52$, $P < 0.05$). This is the same basic pattern exhibited in the comparison between the rock climb and the walk. The HR averages displayed in 5-minute intervals for prusik climbing HR to pre-prusik climb Walking HR is seen in Figure 2.

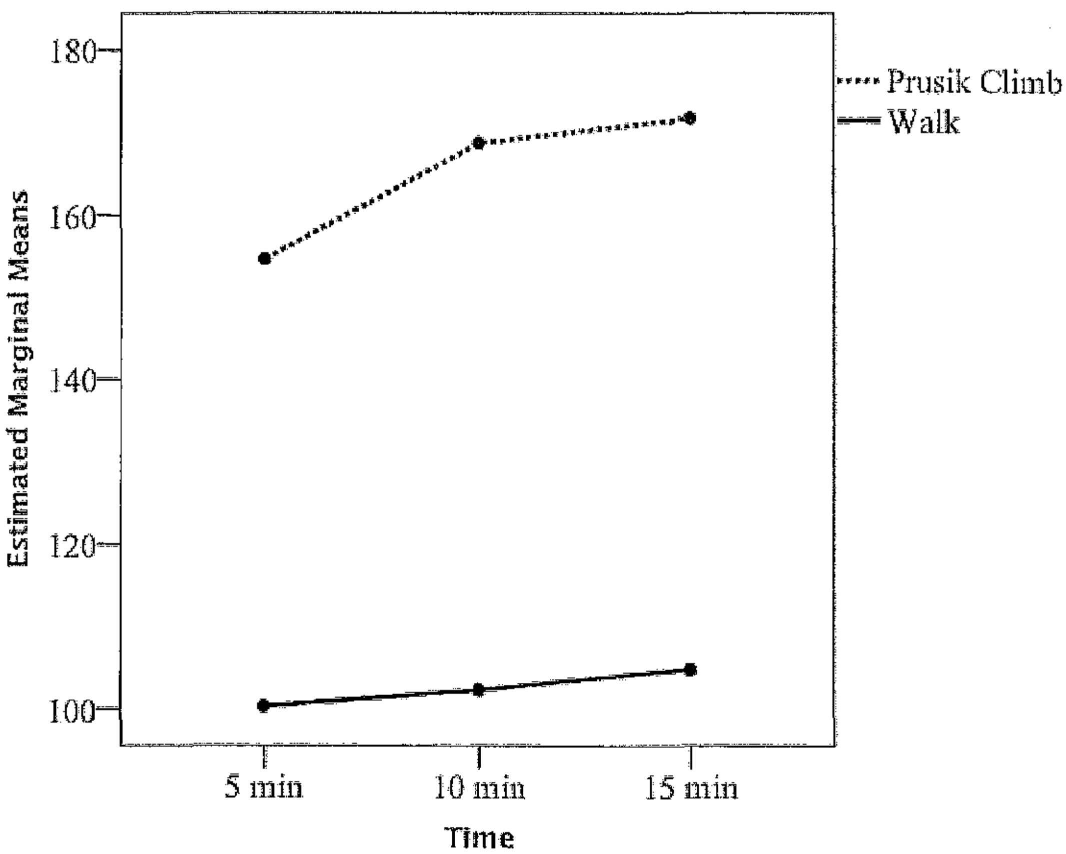

Figure 2. HR of walk before prusik climb compared to HR during prusik climbing.

3. Is there a significant difference in HR at the beginning of the prusik climb compared to the HR at the beginning of the indoor rock climb? The answer to this question is important because it demonstrates the walks before the exercise bout were consistent. When comparing only the 1st minute of HR between rock climbing and prusik climbing by one-way ANOVA, here was no difference in population mean HR (F = 2. 848, df_1 = 1, df_2 = 26, P = 0.103). The mean HR for the first minute and subsequent minutes can be seen in Figure 3.

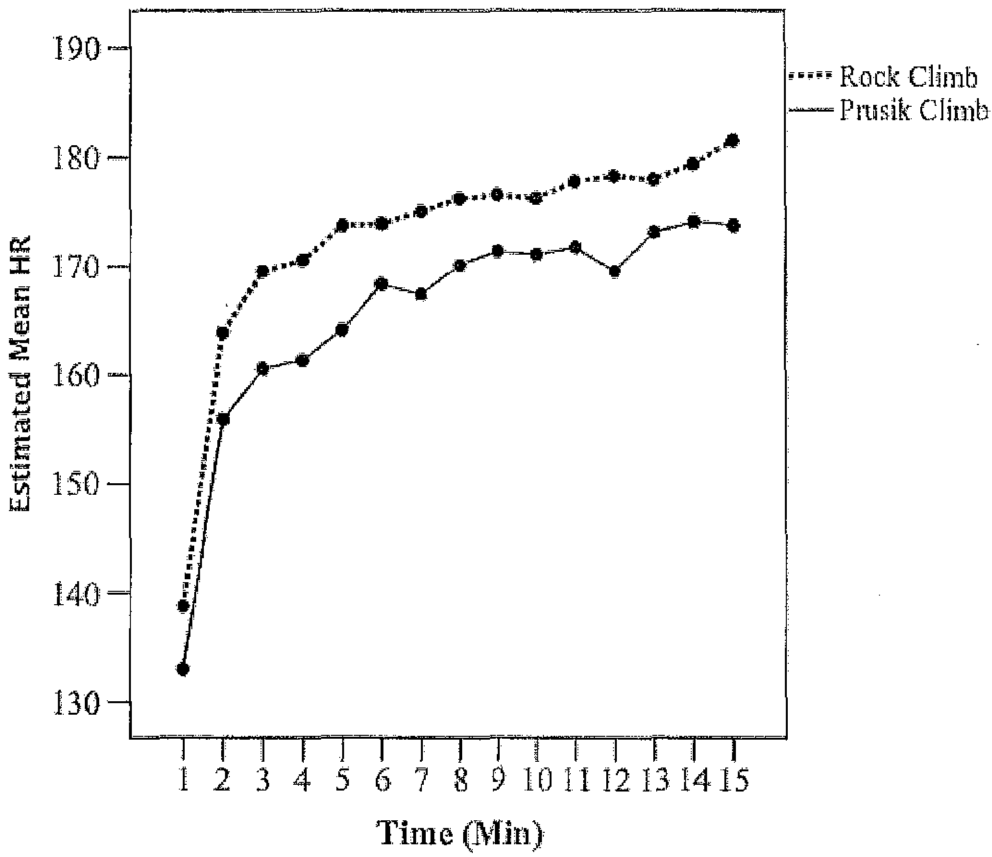

Figure 3. Average HR for each minute for indoor rock climbing and prusik climbing.

4. Is there a significant difference in HR when comparing time, prusik climbing, and rock climbing? There was a significant difference found between the mean rock climbing HR and prusik climbing HR ($F = 9.153$, $df_1 = 1$, $df_2 = 26$, $P < 0.05$). The difference can be seen in Figure 4 with the charting of mean HR at each time interval for rock climbing HR and prusik climbing HR. The mean HR of indoor climbing and prusik climbing are seen in Table 2.

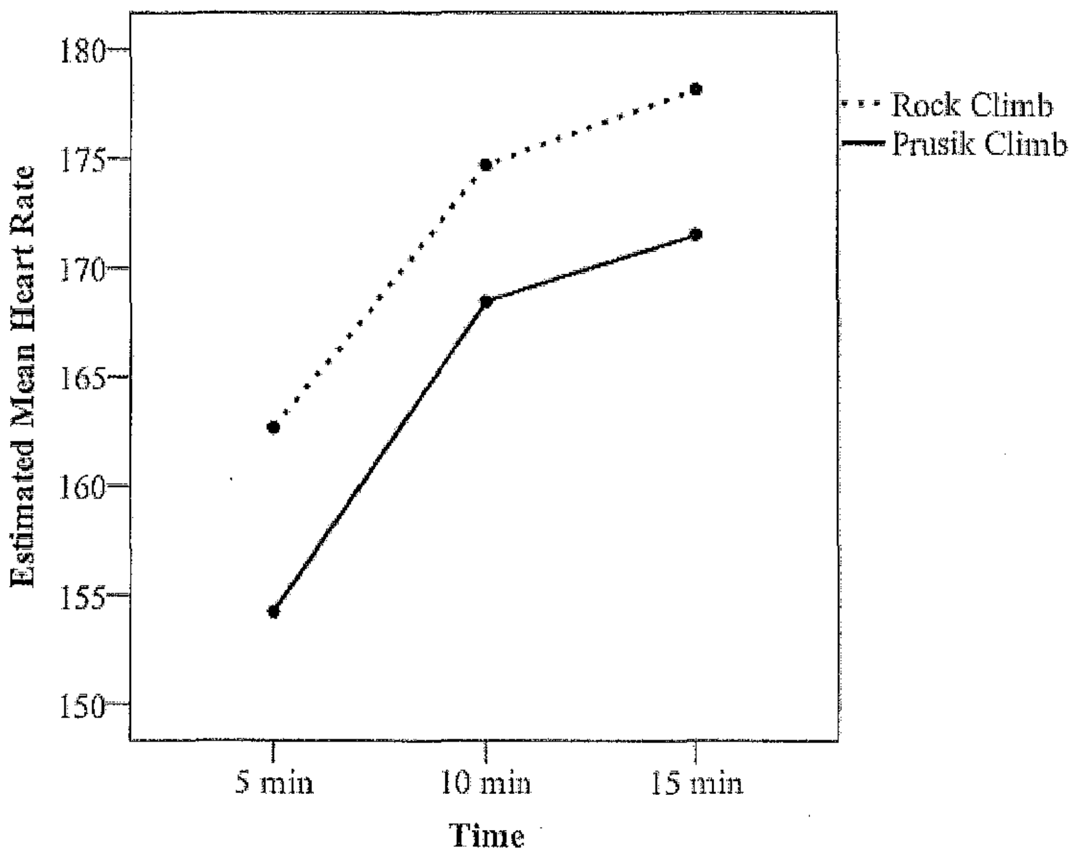

Figure 4. Mean HR displayed at 5-minute interval over a 15 minute exercise bout.

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

	Mean HR Beats per Minutes (BPM)	Lower Bound HR (BPM)	Upper Bound HR (BPM)
Rock Climbing	171. 83	165.25	178.41
Prusik climbing	167.73	158.55	170.91

DISCUSSION

The purpose of this study was to compare the difference in HR responses between indoor rock climbing and prusik climbing. In the current study, while there was no significant difference in HR found between the first minute of indoor rock climbing compared to the first minute of prusik climbing a significant difference in HR was found when comparing the 5-minute, 10-minute, and 15-minute time intervals. 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 MPA and VPA by 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 with moderate to vigorous physical activity (MVPA).

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 is within the MVPA range. (CDC, 2011; Sell 2011). The results of this study found an average prusik climbing HR rate of 167.73. The current study reinforces Sell's et al. findings that prusik climbing is a MVPA.

Indoor rock climbing and prusik climbing can be used within an Adventure Physical Education lesson when framed as an activity to be done as challenge by choice. Evel (2000), Gehris, Myers, and Whitaker (2012), and Watts, Colemean, Clure, Daggett, Gallagher, Sustrich et al. (1999) assessed MVPA and EE in adventure based physical activities. While Gehris et al. (2012) used SOFIT to monitor MVPA in 136 middle school students, it was found on 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. found average EE to be equivalent to 4 METs with peak EE to be equivalent to 6-7 METs. The addition of prusik climbing or indoor rock climbing to high elements and initiatives may increase the amount of time students spend in MVPA when engaging in Adventure Education based activities. Depending on the local operating procedures in physical activity classes, a student can participate and engage in prusik climbing to increase time spent in MVPA instead of waiting to participate in a specific adventure element.

España-Romero, V., Jensen, R. L., Sanchez, X., Ostrowski, M. L., Szekely, J. E., and Watts, P. B. (2012) findings of decreased HR as a route becomes familiar support the decision to use one route with no access to this route during the indoor rock climbing class. In this study participants were able to see the holds available on the route; partipants 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.

Indoor rock climbing in the form of bouldering has been used and tested in physical education settings. Fencl, Muras, Steffen, Battista, and Elfessi (2011) found no significant difference in HR between structured bouldering in the form of a pre-planned activity and bouldering without a specific activity in upper elementary students. Fencl et al. (2011) found a significant difference in pre-bouldering HR and bouldering HR. While the mentioned study did not focus specifically on MVPA, it gives educators an alternative way to engage students in a climbing activity with limited planning for the educator.

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, & 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 had 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, there was sufficient evidence of a significant difference in mean HR when comparing prusik climbing and indoor rock climbing, was valid. While there was significant difference in mean HR, both indoor rock climbing and prusik climbing HR fall into a range of MVPA. The American College of Sports Medicine (ACSM) recommends 150 minutes of MPA per week for adults. (MacDonald, 2014) By comparing the HR of prusik climbing to indoor rock climbing, there are hopes for greater inclusion for prusik climbing in physical education classes across the United States to help foster lifelong activity.

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APPENDIX A

INFORMED CONSENT

Informed Consent

Protocol Title: The comparison of the energy expenditure of prusik climbing, indoor rock climbing, and walking

Principal Investigator: Nathali Niedorowski
27 Mitchell Hall
University of Wisconsin, La Crosse
(608) 433-4367

Emergency Contact: Jeff Steffen
(608) 785-6535

- **Purpose and Procedure**
  - The purpose of this study is to determine the amount of energy expended during prusik climbing and if it is greater than, less than, or equal to rock climbing and walking on novice prusik climbers
  - My participation will involve two 15-minute walks, one 15-minute rock climb on a predetermined route, and one 15-minute prusik climb.
  - The total time requirement will not exceed 1.5 hours over a two day period.
  - All testing will occur in 163 Mitchell Hall.
  - During all tests, I will be wearing a heart rate monitor, strapped around my chest, to monitor my heart rate.
- **Potential Risks**
  - I may experience muscle soreness, substantial fatigue, and discomfort in my palms, fingers, and feet.
  - Individuals trained in Prusik Climbing, belaying, CPR, Advanced Cardiac Life Support and First Aid will be in the testing sites, and the test will be terminated if complications occur.
  - The risk of serious or life-threatening complications, for healthy individuals, like myself, is near zero.
- **Rights and Confidentiality**
  - My participation is voluntary. I can withdraw or refuse to answer any questions without consequences at any time.
  - The results of this study may be published in thesis format, in scientific literature, and presented at professional meetings using grouped data only.
  - All information will be kept confidential using number codes. My data will not be linked with personally identifiable information.

Questions regarding study procedures may be directed to Nathali Niedorowski (608.433.3467), the principal investigator, or the study advisor Dr. Jeff Steffen, Department of Exercise and Sport Science, UW-L (608.785.6535). Questions regarding the protection of human subjects may be addressed to the UW- La Crosse Institutional Review Board for the Protection of human Subjects, (608.785.8124 or at irb@uwlax.edu)

Participant Name
(printed):____

Participant Signature:___________________________________
Date:__________

Researcher Signature:___________________________________
Date:__________

APPENDIX B

PAR Q

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of <u>any other reason</u> why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to <u>all</u> PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

<u>Informed Use of the PAR-Q</u>: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____________________

SIGNATURE ____________________ DATE ____________________

SIGNATURE OF PARENT ____________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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APPENDIX C

REVIEW OF LITERATURE

Introduction

The Prusik knot was first described in 1931 by an Austrian mountaineer named Karl Prusik. (Adams, 2005) The Prusik knot became the primary hitch used in single rope climbing during the 20th century and used through the 1990's. (Adams, 2005) Prusik climbing was also known as single rope ascents when needing to climb a single rope during a rappel. (Long, 2007)As the Prusik knot can be created with a loop of rope, which can use be used as a foothold, or climbers can clip into the loop when climbing a single rope, or created with a length of rope, which may be easier to tie into a harness, or can be closed off to create a loop. (Adams, 2004) As the Prusik knot evolved, the French Prusik came into existence and illustrated in 1944, but left unnamed. (Adams, 2005). The French Prusik hitch was first formally mentioned in the tree industry in 1998 in the United States, and the Army Field Manual called the French Prusik a Telegraph Hitch in 1995. (Adams, 2005) As knots have developed and changed, the nomenclature has evolved and changed. As the French Prusik became used there were specific names given to the type or rope used (a Machard for a loop of rope, or a Valdôtain for a length or rope) and to the number of turns made around the climbing line (a Valdôtain has 7 turns, a Valdôtain tresse only has 4 turns). (Adams, 2004) As technology improved, shunts, jumars, and Ropemans, were created to mimic the Prusik knot so climbers could use technology instead of knots to complete single rope ascents. (Adams, 2004; Long, 2007)

Because of the lack of studies on Prusik and single rope climbing, similar activities using whole body movement such as rock climbing, rappelling, and challenge courses were researched. These alternative, whole body activities were used to gain a deeper understanding of energy expenditure, strength, endurance, and psychological impact Prusik climbing could have on novice participants.

Measuring Energy Expenditure in Prusik Climbing

Sell, Clocksin, Spierer, and Ghigiarell (2011) researched the energy expenditure of Prusik climbing and Nintendo Wii boxing and if average intensity levels are compared to brisk walking. 24 collage aged students with limited to no experience in Prusik climbing and Wii boxing were recruited for the study. Participants completed 30 minutes of brisk walking, 30 minutes of Wii boxing, and 30 minutes of Prusik climbing. Across all measurements Prusik climbing was higher in heart rate, energy expenditure, and oxygen consumption. It was determined slow rope climbing is equivalent to approximately 8 METS, which may vary due to self-selected pace while requiring whole body movement.

This is the only study published to date evaluating the energy expenditure of Prusik climbing. Due to the use of whole body movement, the following are previous studies in rock climbing and rappelling that were used to gain a better understanding of activities requiring whole body movement and the psychological and hormonal responses to a stressor perceived to be a "high-risk sport skill" (Brody , Hatfield, & Spalding, 1988).

Measuring Energy Expenditure in Rock Climbing

Janet (1997) used heart rate and rate of perceived exertion to measure differences between 17 novice climbers and 17 recreational rock climbers. Participants were asked to complete two climbs in the same order as heart was recorded upon the completion or failure of the route, while recovery heart rate was measured 10 minutes after completion of both routes. It was determined rate of perceived exertion was significantly lower in the recreational group than the novice group. Resting heart rate was significantly higher in both male and female novice climbers (6.7-7.7% and 7.7-8.8% respectively). There was no significant difference in recovery heart measured in both groups.

Mermier, Robergs, McMinn, & Heyward (1997) hypothesized the significant differences in heart rate, oxygen consumption, blood lactate, energy expenditure, and respiratory exchange ratio in response to rock climbers climbing routes with variable difficulties. Nine males and 5 females were recruited to complete a 5-minute warm up, three climbs of increasing difficulty with 15 – 20 minutes of rest between reach climb. Oxygen consumption was measured during the last minute of each climb; blood was taken before the first climb and after each climb during the 1-2 minute of rest. Mermier at al. used the Scheffé post hoc test to identify significant differences in the means. While there was no significant difference found in the respiratory exchange ratio, there was a significant difference between heart rate and post blood lactate at the end of each climb. Oxygen consumption was found to be similar to moderate paced walking while heart rate had increased between 74 – 85% of age predicated maximal heart rate.

Sanders (1999) compared physiological responses between novice and advanced rock climbers climbing routes with moderate difficulty. Using 20 male volunteers (10 novice, 10 advance) all experienced a 5 minute warm up on a stationary bike, climbed three routes while heart rate and oxygen consumption was being measured. There was a 10-minute resting period between each climb. A two-minute baseline of oxygen consumption was measured and heart rate was averaged and recorded every twenty seconds. At the end of each climb, climbers would rate their perceived exertion on a 6 – 20 rate of perceived exertion Borg scale. The mean rate of perceived exertion scores was found to be significantly different between the novice and advanced climbers. A change in rate of perceived exertion between each route climb was noted. There was a significant difference in oxygen consumption, caloric expenditure, and heart rate between each route, with an increase seen as the difficulty of the route increased.

Betuzzi, Franchinni, Kokubum, and Kiss (2007) tested 13 climbers (six elite, seven recreational) to determine if climbers would experience increasing energy expenditure and anaerobic contribution as route difficulty increased and if elite climbers would have a lower energy expenditure compared to recreational climbers during easy routes. Testing was completed in three session intervals with 48 hours to one-week time between each session. Session one anthropological measurements, peak-arm oxygen consumption, and Wingate tests performed. During session two climbers became familiar with the gym and climbing facility, and session three all climbers climb while oxygen consumption and heart rate was measured during the climb while blood lactate was measured at the one, two, and three-minute mark post-climb. Heart rate, blood lactated, and W_{total} was higher in the recreational group compared to the elite climbers, and heart rate during the easy route was significantly lower for elite climbers compared to other routes.

España-Romero, Jensen, Sanchez, Ostrowski, Szekely, & Watts (2012) 9 expereinced climbers (eight male, one female) completed nine specific ascents in an indoor route over a 10-week period, each climb being one week apart. Climbers were not required to use all 35 holds and were only allowed to use "natural" features for foot support. After anthropolical data measured, wieght was measured before each climb without shoes, climbers completed a warm up and ascent with a portable air analizer and heart rate monitor. Rate of percived exertion was measured apon descent. A 10 minute recovery was also monitored. As ascents were repeated a decrease in climbing time and energy expenditure was measured. With the decrease in climbing energy expenditure there was an increase in enegery expenditure during recovery. The 9th ascent had a lower total engery expenditure compared to the 1st ascent total energy expenditure.

Watts and Ostowski (2014) measured oxygen uptake and energy expenditure in 29 children (18 male, 11 female) in rock climbing activities similar to physical education programs. While wearing a portable air analyzer, participants were asked to complete one warm up lap on a island rock wall, rest for five minutes, complete continuous movement to the right for five minutes, rest for five minutes, then complete ten minutes of interval climbing (one minute climbing, one minute rest). Watts and Ostowski found average and peak oxygen consumption was high in five minutes of continious climbing than in the 5th interval of interval climbing. During the continuous climb, oxygen consumption increased rapidly at the beginning then there was a gradual increase in oxygen consumption as time progressed. Oxygen consumption levels did not go back to pre-climb levels during the five minutre rest inbetween climbing trials. Both trials have significan aerobic components and the resaults suggest interval and continuous climbing meet desired, submaximal exertion, intensity levels.

Overall there was a difference in percieved exertion and energy expenditure between different levels of climbers. (Bertuzzi et al., 2007; Janet, 1997; Sanders, 1999) There was also a difference in heart rate and blood lacte related to the difficulty of a route. (Mermier et al. 1997; Giles, Rhodes, and Tauton, 2006) This was further supported in the work of España-Romero et al. (2012) due to the decrease in energy expenditure observed as a route became familiar to the climbers. Watts and Ostowski (2014) also found a difference in energy expenditure when comparing continuous climbing to interval climbing in youth.

Strength and Body Composition of Climbers

Giles, Rhodes, and Tauton (2006) aimed to uncover any physiological factors that may improve rock-climbing performance and to determine key features (anthropometry, muscular strength and endurance, flexibility, and physiological and metabolic responses to climbing) between elite rock climbers and the general population. The anthropometry determined elite climbers to have a lower body fate percentage, lower body mass, and a higher ape index than the general population. While all are beneficial to climbing, anthropometry features are not a prerequisite for climbing success. Muscular strength and endurance can influence climbing performance; climbers can benefit from increased finger strength and increased strength and endurance in the arms and shoulders. Giles et al. found elite climbers to have an increased hand-related strength in relation to body weight while forearm and handgrip endurance in elite climbers are slower to fatigue and have better recovery compared to the general population. Flexibility was tested via the sit and reach test, which is not climbing specific. The results suggested flexibility was not a determinate of climbing success. The physiological and metabolic responses to climbing were different, in the general population and elite climbers. As the difficulty of climbing increased, there was an increase in oxygen consumption, energy expenditure, and heart rate. (Giles et al. 2006; Sanders, 1999) Giles et al. also found an increased ability to tolerate and remove blood lactate while climbing in elite climbers, which is beneficial to a climber's success.

Lopera, Porcari, Steffen, Doberstein, & Foster (2011) measured the changes in strength, endurance, and flexibility after 16 college students participated in seven weeks of indoor rock climbing, evaluated the changes and their correlation with climbing performance, and compared these 16 college students with a second group of 16 college students with two or less rock climbing experiences. All participants completed a pre and post-test consisting of anthropologic data, skin fold thickness, handgrip strength, modified seat-and-reach, pinch strength, handgrip endurance, one-repetition maximal lateral pull-down, bent-arm hang, foot rise, leg span test, and climbing session where participants continuously climbed until failure and duration of the climb was recorded. At the start of the study the control group and the climbing group had no significant differences. By the end of the seven weeks, the climbing group increased in strength and endurance except in lateral pull-down, there was an increase in climbing time and climbing score. There was no significant increase in flexibility found in the climbing group compared to the control group.

Schöffl, Schöffl, Dötsch, Dörr, & Jüngert (2011) compared physical active adolescents (14 total, eight male, six female) with high-level adolescent climbers (16 total, nine male, seven female) by measuring anthropometrical, developmental, and hormonal data. There was no significant difference between climbers and non-climbers in eating habits or puberty development and cycles. Male climbers were found to have a larger Ape Index than female climbers. Male climbers and male non-climbers had similar height, weight, and body mass index to the standard deviation. Female climbers had a significantly lower body weight and body mass index score compared to female non-climbers. Climbers had a significantly lower skin fold tests compared to non-climbers. Leptin values were significantly lower in female climbers. Overall, adolescent climbers do not have hormonal and growth abnormalities in leptin and development.

Laffaye, Collin, Levemier, & Padulo (2014) sought to validate a specific power test on athletes and assess rock-climbing profiles between boulderers and route climbers. 36 climbers were separated into three groups (novice, skilled, elite) separated into two samples (bouldering or route climbing). After height, arm span, body fat percentage, muscle mass percentage, body mass index, and APE index, participants hung from two jug holds, completed a pull up and slapped measuring board (Aj Test) while wearing an accelerometer. The test was repeated three times, keeping the best score, and the test was repeated again one week later. Laffaye et al. determined the Aj Test to appear to be reliable through intra and inter session reliability and validity compared to the accelerometer. Through this test, boulderers were profiled as powerful and quick while route climbers were classified as weak and slow or weak and quick. The higher a climber scored in the Aj Test there was a positive correlation of in climber ability.

Elite climbers had an increased hand strength and increased endurance in the forearms and handgrip. (Giles et al.; 2006) For novice climbers who began a seven week training program, the participants in the climb group experienced an significant increase in muscular strength and endurance. (Lopera et al. 2011) In concern of developmental differences for adolescent climbers, there were no abnormalities found between adolescent climbers in hormonal and growth development compared to physically active adolescents. Schöffl et al. (2011) created the Aj Test to test the upper body to profile climbers based on their responses in the AJ test.

Finger and Hand Grip / Strength in Rock Climbers

Quaine, Vigouroux, and Martin (2003) had 20 right handed males (10 elite climbers, 10 sedentary climbers) hold a crimp style grip while taking surface EMG measurements to determine forearm fatigue and fingertip force. Participants were asked to use the crimp style grip on a steel hold for five seconds at maximum grip. After a five minute rest participants were asked to repeat the test for three trials. After the three trials, participants had 10 minutes to rest, and then were asked to hold the grip at 80% contraction for 5 seconds with 5-second rest until they fell below the 70% contraction mark. There was a significant difference in fatigue time between elite climbers and sedentary climbers (0:3:05 vs 0:1:55).

Danion (2008) tested 5 male elite rock climbers and 5 male athletes in other sports to determine how grip force safety margin in elite rock climbers change between the weight and duration of holding the object. All participants were asked to prevent the load from slipping by pinching the sensors between their thumb and forefinger. All participants were tested using each hand, two different loads, and two different durations. The entire protocol was repeated three times per subject. While little difference was recorded in muscular involvement between the two subject groups, relative grip force increased for heavier loads, and climbers had a larger maximal voluntary contraction. Both groups had similar relative safety margins except in light loads, both groups had a lower relative safety margin when holding a heavier object, and an increased relative safety margin with holding the sensors for a longer period.

Amca, Virgouroux, Aritan, and Berton (2012) had 11 climbers (10 males, one female) recorded 42 sessions where participants hung from matching holds until fingers slipped to see if chalk will increase the finger-hold friction coefficient on sandstone and limestone while observing if humidity and temperature will have an effect on finger-hold friction. Extreme tempurature and humidity was not measured. Amca et al. found a signifcant effect of chalk on the coefficint of friction and the effect of chalk on limestone and sandstone comapred to finger-hold friction without chalk. There was no significant correlation between humidity / temperature and friction.

In the specifics of handgrip and hand strength in climbers, Quaine et al. (2003) found a significant difference between endurance of the handgrip in elite climbers and the handgrip in sedentary climbers. In a grip test conducted by Danion (2008) elite climbers were found to create a larger maximal contraction compared to their athletic counterparts. Comparing handgrip with and without chalk on two different rock types, Amca et al. (2012) found a significant effect of chalk on the coefficient of friction when tested on limestone and sandstone.

Psychological Impact of Rappelling and Rock Climbing on Participants

Brooke and Long (1987) examined the level of aerobic power and efficacy of coping with real situations in 27 males, hypothesizing the higher the aerobic power then the higher rate of recovery in psychological, physiological, and hormonal measurement after exposure to the stressor. The males were divided into two groups based on their fitness levels and were tested over a 3 day period. Maximal oxygen consumption was tested on day one. On day two subjects were had blood taken to measure a baseline of cortisol and catecholamine. On day three subjects took a subjective anxiety test before and after the rappel, blood was taken before the rappel, immediately after the rappel, 15 minutes after the rappel, and 30 minutes after the rappel. While all groups experienced a change in the markers, heart rate was lower in the fit group overall. The Cortisol levels tended to show anticipatory responses before the rappel and did not return to baseline after rappelling was completed. There was a week support of the hypothesis.

Brody , Hatfield, & Spalding (1988) tested 34 college age males and hypothesized if participants were exposed to the mastery approach of rappeling they would experience an increase in self efficacy and decrease anxiety towards rapelling where a possible cross-effect may be expereinced. The 34 males were divided into a control group and an experiemental group. The experimental group completed two 2 hour session to master rapelling. At the time of rapelling both groups were monitored for muscle tension via EMG, heart rate, and state anxiety reactions. The control group had higher EMG, heart rate and state anxiety than the mastery based experiemental group. However the was no significance found when crossing over the experience in efficacy in a social situation.

Draper , Dickson, Fryer, Blackwell, Winter, & Scarrott (2012) tested 19 experienced climbers (13 male, six female) to determine the relationship between subjective anxiety, self-confidence, and plasma cortisol concentration for on-sight lead or top-rope climbing. Over three-session maximum oxygen consumption was tested the first session, blood samples for cortisol and practice climb happened during session two. During session three participants were randomly assigned to lead or top rope climbing; blood was 30 minutes before assent and after being informed. There was a negative linear relationship between self –confidence and the concentration of plasma cortisol. A linear relationship was found between cognitive anxiety and plasma cortisol concentration and a significant linear relationship between subjective somatic anxiety and the concentration plasma cortisol. There was no significant differences between lead and top-rope climbing groups. Anxiety is linear in on-sight ascent where the increase of self-confidence has a decrease in cortisol levels.

Anxiety has been found to have an impact on cortisol level and heart rate in the body climbers and rappelers when faced in stressful situations. (Brody et al, 1988; Brooke and Long,1987; Draper et al. 2012). Brooke and Long (1987) had a decrease in anxiety levels measured by heart rate, muscle tension, and state anxiety when looking at the mastery group compared to the control group. Brody et al. (1988) found anticipatory responses in the cortisol levels and participant cortisol levels did not return to baseline measures after the climb was completed. Draper (2012) found a decrease in anxiety levels measured by cortisol levels present in the blood when participants had a high self-confidence in on-sight climbing.

Adventure and Outdoor Activities

Evel (2000) examined heart rate differences in 17 students with and 21 students without cognitive disabilities during a challenge course experience. Students were asked to sit quietly for 2 minutes to measure a baseline heart rate, then heart rate was measured at five second intervals during three distinct phases, pre, during, and post climb. There was no significant difference in heart rate between the two groups across all phases, however a significant differences was found between the two groups by phases using F ratio. There was a significant difference found between phases. Based on this research there is no physiological reason to have different protocols at rope courses, but personal and emotional safety always needs to be taken into consideration.

Eglington and Broderick (2007) presented a unique link between education for male youth in Australia and meeting new social and ecological sustainability through Outdoor Education. Their model of Outdoor Education is adventure based and utilizes skills in decision making, personal development, problem solving, and leadership to develop knowledge of environmental, economic, societal sustainability, health, and fitness. Integrating this program throughout educational institutions will allow at-risk youth to develop lifetime skills, such as cooking, nutrition, swimming, and self-management skills. This program can also be used to engage male students in their learning to help foster lifetime skills and global awareness.

Gehris, Myers, and Whitaker (2012) observed seven public middle schools in five different school districts during four to eight Adventure Physical Education lessons. Using SOFIT observers observed students, lesson context, teacher promotion, while coding the type of adventure activity. The mean percentage of time spent in moderate to vigorous physical activity in each lesson was 28.3% ± 16.3%. 45% ± 17% of time was spent standing and 25.9% of the time ± 18.3% was spent sitting. When engaged in high elements 40% of time spent was in moderate to vigorous physical activity, while 31.5% of time spent in high elements was inactive. Compared to traditional physical education activities there was less time spent in moderate to vigorous physical activity. Gehris et al. suggest offering stations of Prusik climbing to increase time spent in moderate to vigorous physical activity while students wait to rock climb. Other suggestions include teaching students to belay, rotate through low elements in small groups, and offering more positive feedback during activities to help increase moderate to physical activity.

In regards to students with and without cognitive disabilities there was no significant difference found in physiological responses across all phases of participation. (Evel, 2000) Eglington and Broderick call for Outdoor Education to integrate personal and lifetime skills with ecology and environmental awareness to create a unique cross-curriculum program to engage students in lifelong physical activity. When comparing adventure and outdoor physical activities, such as rock climbing, initiative, low, and high elements, it was found students spend more time being inactive than active during a class compared to traditional physical activities. (Gehris et al, 2012).

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