3RD ROCK CLIMBING RESEARCH CONGRESS

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PRESENTED BY
School of Health &
Human Performance

NORTHERN MICHIGAN
UNIVERSITY

2016 IRCRA
International Rock Climbing Research Association

Contents

Welcome!

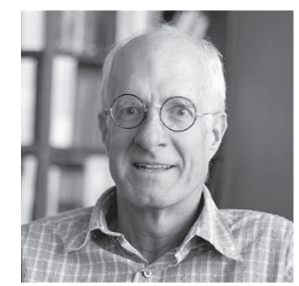
We are excited to welcome you to the 3rd International Rock Climbing Research Association Congress hosted in Telluride, Colorado, USA. This jam-packed weekend is comprised of a diverse mix of innovative scientific research highlighting the latest information and trends regarding climbing and its applications. The oral research presentations selected for this congress continue to build and expand on previous knowledge and encourage future climbing research. An international assortment of presentations ranging from new student authors to well-established researchers awaits. The conference multi-day schedule includes eight research sessions (with four, 10-min talks/session) on a broad range of climbing topics including clinical, biomechanical and applied sciences. Additionally, 4 keynote presentations are highlighted emphasizing the research history, physiology, nutrition and application of the science for coaches and participants in the sport. We feel very fortunate that our closing dinner Sunday evening showcases a special presentation by one of the most influential climbers of all time; Lynn Hill. Please note each day, light morning refreshments are provided as well as a sack lunch to eat wherever you'd like. Dinner is on your own Saturday evening.

Thank you to our supporting agencies, sponsors and to Liz Drum for designing our cover and posters. Organizing an international conference from afar has been a substantial collaboration among many folks and we'd like to add a special thank you to: our hard working volunteers, the Madeline Hotel for housing our congress and for their warm hospitality, and the 2016 IRCRA Congress committee.

Nick Draper, PhD
University of Derby

Scott Drum, PhD
Northern Michigan University

Lanae Joubert, PhD
Northern Michigan University



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Special Thanks to **Liz Drum** for design of the *Congress Poster* and *Proceedings* book covers.

Program Overview

Friday, August 5, 2016

2.00 pm	**Registration Opens**
7:00 pm	**Welcome and Announcements**
7:15pm	**Historical Keynote: A Physiological Model for Rock Climbing – The First 2000 Years** ***P. Watts*, Northern Michigan University, USA**
8:15 pm	Social (wine, beer and snacks)

Saturday, August 6, 2016

8:00 am	**Registration Opens**
8:20 am	**Announcements**
8:30 am	**Keynote: A Physiological Model for Rock Climbing – Today and Beyond** ***V. España-Romero***, Universidad de Cádiz, Spain
9:45 am	**Research Session I**
	N. Draper - Assessment of climber performance: a multi-centre trial
	J. Sveen - Strength and forearm volume differences in boulderers and sport climbers
	V. Vereide - Correlation between relative peak isometric force and RFD and climbing performance
	J. Balas - Recovery during intermittent testing of finger flexor strength in rock climbers - a predictor of climbing ability?
10:45 am	**Break**
11:15 am	**Research Session II**
	K. Phillips - The effect of cold ambient temperatures on climbing-specific finger flexor performance
	D. Aras - The effects of long term sport rock climbing training on heart rate variability in sedentary adults
	S. Drum - Heart rate, perceived effort and anxiety during top-rope and lead rock climbing
	K. Hewitt - Effect of hypohydration on climbing to failure on a treadwall
12:15 pm	**Lunch - provided**

1:15 pm	**Expert Panel Keynote Session: Nutritional Issues in Rock Climbing** ***L. Joubert*** - Northern Michigan University, USA ***A. Larson*** - Southern Utah University, USA ***S. Weber*** - University of Colorado - Colorado Springs, USA
2:30 pm	**Research Session III**
	V. Schoffl - Slap lesions in rock climbers: outcome after primary long biceps tendon tenodesis.
	C. Lutter - Pulling harder than the hamate tolerates: evaluation of hamate injuries in rock climbing and bouldering
	M. Simon - Functional outcome after surgical repair of rotator cuff tears in rock climbers
	C. Lutter - Rock climbing related bone marrow edema of the hand: a follow-up study
3:30 pm	**Break**
4:00 pm	**Research Session IV**
	M. Anderson - Evaluating the Rock Prodigy training method
	M. Anderson - Finger strength improvements with the Rock Prodigy Training Center hangboard
	E. Lopez-Rivera - Comparison of the effects of three hangboard training programs on maximal finger strength in rock climbers
	E. Hermans - Effect of maximal and local muscle endurance strength training on climbing performance and climbing-specific strength in recreational climbers: a randomized controlled trial

Sunday, August 7, 2016

8:30 am	Announcements
8:45 am	**Keynote: Bringing the Science to the Climber and Coach** ***Eric Hörst*** - Author of Training for Climbing
10:00 am	**Research Session V**
	M. Simon - Biomechanics, pathomechanism and risk factors of epiphyseal stress fractures in young high level climbers
	G. Oettl - The influence of low-friction quickdraws on impact forces in climbing falls
	M. Kilgas - Magnesium carbonate (chalk) increases hang time until failure in rock climbing

10:45 am	**Break**
11:15 am	**Research Session VI**
	G. Gonzales - Risk taking and ethics in rock climbers
	P. Czermak - Anxiety level and ability to climb routes in recreational indoor climbing
	F. Baux - Study of practical reasoning in regional and national level climbers during the ascent of an unknown natural boulder
	A. Ilgner - Importance of attention in mental training analyzed through falling
12:15 pm	**Lunch - provided**
1:00 pm	**Research Session VII**
	P. Hoffmann - Long-term radiographic adaptations to the stress of high-level and recreational rock climbing in young athletes
	A. VanHorn - Hang board performance time across multiple hangs in normoxia and normobaric hypoxia
	J. Miller - Comparing climbing kinematics of children with and without pathological gait
2:00 pm	**Break**
2:30 pm	**Research Session VIII**
	E. Dagnan - Motivation and habit formation: an exploration of rock climbing and its implications for exercise prescription
	M.J. Epelde-Merino - Case study of a climbing activity as an educational tool for primary school children throughout a whole academic year
	S. Davis - Climbers for bat conservation: engaging rock climbers through citizen science
3:30 pm	Free Time
6:00 pm	Closing Buffet
	Featured Guest Presentation ***Lynn Hill*** – Legendary climber and athlete

Assessment of climber performance: A multi-centre trial

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***Summary* – The assessment of climber performance through a battery of sport-specific tests has remained of interest to climbers, coaches and researchers for a number of years. The International Rock Climbing Research Association (IRCRA) was formed in 2011 to bring together researchers in the field of rock climbing. In 2014 members of IRCRA agreed to complete a multi-centre trial to develop a battery of tests for rock climbing. This paper presents preliminary findings from the data collected in six countries and from the 114 participants who took part in the research.**

INTRODUCTION

Successful performance in rock climbing has been suggested to rely significantly on a climber's strength, power, flexibility and endurance [1]. As a relatively new sport to research inquiry, few climbing-specific performance tests have been developed. More recently, however, the development of climbing-specific tests has had an increasing research focus in order to provide climbers, coaches and researchers with a means through which to assess climber performance and training effect [2,3]. The IRCRA was formed to bring together researchers, from around the world, with a research interest in the sport [4]. In 2014 IRCRA launched a multi-centre trial, the aim of which was to develop a battery of valid and reliable tests to assess the key physiological performance parameters.

METHODS

The study was co-ordinated from the United Kingdom (UK). One hundred and fourteen climbers (37 female, 77 male) from Austria (12), Chile (21), Czech Republic (15), France (15), Spain (15) and UK (36) signed informed consent forms and agreed to participate in the study. The mean (± SD) age, years climbing, climbing sessions per week and climbing performance were 26 (± 6) years, 6.5 (± 5.5) years, 2 (± 1) sessions pw and 19 (± 4) pts on the IRCRA scale respectively. Climbers completed 10 tests over three visits to their local data collection centre. The tests were foot-raise with (T1) and without (T2) rotation, finger strength (T3), finger hang (T4), power slap (T5), bent-arm hang two-arm (T6) and single-arm (T7), pull-ups (T8), plank (T9) and 90 º leg raise (T10). The assessments were completed as described in the test battery handbook (www.ircra.rocks). Climber abilities and groups were reached using the grading comparison scale proposed by Draper et al [4]. Data were analysed using SPSS version 22.

RESULTS

Mean (± SD) height, mass, body fat % and ape-index for males were 175 (± 6) cm, 70 (± 9) kg, 14 (± 5) % and +5.5 (± 5) cm and for females were 163 (± 7) cm, 59 (± 8) kg, 25 (± 5) % and +2 (± 3) cm respectively. Fifty-six climbers spent 50%, or more, of their time sport climbing, 47 bouldering, 10 trad climbing and 4 expressed no major discipline. Initial analysis of results indicated that there was a non-significant relationship between maximal self-reported ability and T1, T2 and T10. Significant relationships were found between self -report ability and T3 ($r = 0.56$, $p < 0.0005$), T4 ($r = 0.67$, $p < 0.0005$), T5 ($r = 0.6$, $p < 0.0005$), T6 ($r = 0.5$, $p < 0.0005$), T7 ($r = 0.5$, $p < 0.0005$), T8 ($r = 0.65$, $p < 0.0005$) and T9 ($r = 0.3$, $p = 0.001$).

DISCUSSION

Initial analysis of the data suggests that the flexibility measures (T1 and T2) and the 90º leg raise did not significantly correlate with climbing performance and therefore appear to be less likely to influence climbing performance or to provide sport-specific measures of flexibility and endurance. Tests 3 – 9 had significant relationships with performance and good levels of repeatability ($p < 0.05$). A finalised battery of tests based on the findings from this study is under development and will be presented at the Congress and subsequently published in an international journal and on the IRCRA website.

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Strength and forearm volume differences in boulderers and sport climbers.

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Summary – Twenty-eight participants were divided into three groups: control (n=10), sport climbers (n=9) and boulderers (n=9) to investigate the determinants of grip strength between climbing disciplines. Forearm volume (FAV) was measured using water displacement method. Maximal volitional contraction (MVC) was assessed using an open crimp grip on a climbing specific fingerboard apparatus. There were no significant differences in FAV between disciplines. However, there was a significant main effect for MVC and MVC/FAV across all groups. Boulderers had higher MVC than sport (MD=7.5 CI=1.8-13.2) and controls (MD=17.7 CI= 11.9-23.6) and sport climbers was higher than controls (MD= 10.2 CI = 4.5-15.9. The findings suggest that the greater MVC seen in boulderers and sport climbers may be a result of neural adaptations, not muscular hypertrophy.

INTRODUCTION

Previous research suggests that bouldering should be treated as its own rock climbing discipline due to the potential physiological differences between sport climbing and bouldering [1, 4]. Although some components of performance are equally important for the disciplines, the physiological attributes of the component may be different. Grip strength is clearly important for both sport climbing and bouldering; however the strength and endurance aspects of this appear to differ between the disciplines. Boulderers have been found to have a higher MVC compared sport climbers, but the reason remains unclear [1, 3]. Therefore, the purpose of this study was to investigate whether an improved MVC seen in boulderers is a result of muscular hypertrophy.

METHOD

Twenty-eight participants were divided into three groups: control (N=9), bouldering (N=9) and sport climbers (N=10). Average climbing ability for boulderers and sport climbers was 22 and 17 on the IRCRA reporting scale. Forearm volume was measured to the nearest 0.5mL using the water displacement method in a rested condition [2]. The hand was initially immersed and the water discarded. This was followed by immersion of the arm up to the elbow crease. The result was expressed as absolute volumes, and was normalized to handgrip strength. The maximal volitional contraction was performed using an open crimp on a modular rock climbing hold (Uprising Ventures, Christchurch, New Zealand), mounted on a climbing specific fingerboard apparatus. The participants were given three attempts to achieve the highest score. One-way ANOVA and post hoc Bonferroni were used to determine potential differences in the dependent variables. The pairwise comparisons are displayed alongside mean difference (MD) and confidence intervals (CI).

RESULTS

Significant main group effects were observed for MVC and MVC/FAV. There was no significant main effect for FAV. Pairwise comparisons revealed that boulderers had a significantly higher MVC than both sport climbers (MD=7.5 CI=1.8-13.2) and controls (MD=17.7 CI= 11.9-23.6). Sport climbers also had a significantly higher MVC than controls (MD= 10.2 CI = 4.5-15.9). The pairwise comparison also revealed that boulderers had a significantly higher MVC/FAV than both sport climbers (MD=0.006 CI=0.0-0.012) and controls (MD= 0.013 CI= 0.007-0.019), and that of sport climbers was also significantly higher than controls (MD= 0.007 CI=0.001-0.013).

Table 1. Anthropometric and grip strength data.

	Control	Sport climbing	Bouldering
Body fat %	16.97 ± 8.39	14.9 ±7.96	10.01 ± 3.89
Circumference (cm)	26.67 ± 1.95	27.56 ± 1.91	29.17 ± 1.10*
Forearm Volume	968.7 ± 195.9	1026.3 ± 197.9	1115.9 ± 100.4
MVC (Kg)	19.2 ± 2.5	29.4 ± 4.0*	36.9 ± 6.9**
MVC/BW	0.26 ± 0.05	0.397 ± 0.06*	0.50 ± 0.08**
MVC (N) /FAV	0.20 ± 0.04	0.27 ± 0.05*	0.33 ± 0.05**

* Significant different from control ($p<0.05$).
** Significant different from control and sport ($p<0.05$).

DISCUSSION

The main finding of this study is that boulderers have a significantly greater MVC and MVC/FAV compared to sport climbers. However, this may not be due to hypertrophy as no differences in FAV were found. This is in agreement with Fachini *et al.* (2013) who observed that boulderers had a higher MVC and rate of force development (RFD) than sport climbers. This may reflect chronic neural or muscular adaptations induced by several years of explosive muscle contractions that are required in bouldering [1]. Future studies should investigate the physiological or biomechanical mechanisms underpinning finger strength for a greater understanding of how to optimally train in order to improve performance in bouldering and sport climbing.

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Correlation between relative Peak-, isometric Force and RFD and climbing performance

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Summary – The correlation between the muscle properties and climbing performance were tested in twenty male sport climbers. Participants were categorized into four levels of climbing performance. They were all tested in Relative Peak Force (PF), Rate of Force Development (RFD), maximum isometric Force (isoF), grip strength, finger hang test, muscle thickness of finger flexors and body composition. Significant correlations to climbing performance were found for relative PF (r = 0.77), RFD (r = 0.61), relative isoF (r = 0.73) and finger hang (r = 0.83). These measures correlates moderate-to-high to climbing performance and should therefore be included in a test battery for sports climbers.

INTRODUCTION

The most prominent physical factors in sport climbing are strength and/or endurance in fingers and the muscle strength in the upper extremity in combination with body composition [1, 2]. Studies reporting sport specific strength and climbing performance have either used climbing test routes or climbing tests such as bent-arm hang, finger hang, finger strength in a dynamometer and pull-ups [1, 2]. For example has previous studies reported a high correlation between finger strength and climbing performance among elite climbers [1, 3, 4, 5]. However, the most common and used climbing tests have tested local finger endurance (i.e. dead hang) or maximal strength (finger dynamometer), and not peak strength or Rate of Force Development (RFD). Further, it`s generally accepted in the scientific literature a near perfect linear relationship between maximal isometric force and the cross section area of the muscle, but it has never been examined in the forearms muscles among climbers. Therefore, the aim of this study was to examine the correlation between Relative Peak Force (PF), Rate of Force Development (RFD), maximum isometric Force (isoF), body compsiton and cross section area of the two forearm muscles with climbing performance.

METHODS

In this cross-sectional study, twenty male sports climbers with red point climbing performance french grade 5a - 8a+ participated. The climbers were asked about their climbing performance, and divided into four different performance level groups based on previous categorization: 1) lower grade, 2) intermediate, 3) advances and 4) elite [6]. The participants hang on a 23 millimeter wooden list (Woody grips, Metolius, USA). The elbow angels were adjusted to 90˚with a downward force in a waist belt from a climbing harness. The waist belt were connected with static aramid cord to the anchored force cell (Ergotest Technology AS, Norway). The participants were instructed to generate maximal force as rapid as possible and maintaining the force for a minimum of three seconds. The force cell measured Relative PF, RFD was calculated as a mean over a 200 msec on the steepest part of the curve and the maximum isoF was calculated as the mean over a 1500 msec window.

Finger hang test was performed on the same list. Grip strength on dominant hand was measured with a hand dynamometer (Baseline® Hydraulic Hand Dynamometer, Fabrication Enterprises, Inc. Elmsford, NY, USA). Body composition was measures with a Tanita MC 180 (Tanita Corp, Japan). Cross section of m. flexor digitorum superficialis and m.fexor digitorum profundus were measured with an ultrasound (Echo Blaster Cest-1Z, Telemed UAB, Litauen).

RESULTS

There were significant correlations between climbing performance and relative PF, RFD and relative isoF. Finger hang was highly correlated to climbing performance, however, relative grip strength showed no significant correlation to climbing performance. Relative muscle cross section was significant correlated to finger hang, relative PF, relative isoF and grip strength, but not to RFD and climbing performance (see table 1).

Table 1. Correlation between finger hang, peak isometric muscle strength, grip strength, muscle cross section and climbing performance. Bold font shows correlation (r), whereas italics shows significant- level (P-value).

	Climbing performance	*Finger hang*	*Relative PF*	*RFD*	*Relaltive isoF*	*Relative Grip strenght*	*Relative M.cross section*
Climbing performance	▪	*≤0.001*	*≤0.001*	*0.004*	*≤0.001*	*0.144*	*0.194*
Finger hang	**0.83***	▪	*≤0.001*	*0.002*	*≤0.001*	*0.005*	*0.01*
Rel. PF	**0.77***	**0.85***	▪	*≤0.001*	*≤0.001*	*0.001*	*0.009*
RFD	**0.61***	**0.66***	**0.87***	▪	*≤0.001*	*0.017*	*0.283*
Rel. isoF	**0.73***	**0.84***	**0.96***	**0.79***	▪	*≤0.001*	*0.002*
Rel. Grip strenght	**0.34**	**0.60***	**0.67***	**0.53***	**0.73***	▪	*0.001*
Rel. M.cross section	**0.31**	**0.56***	**0.57***	**0.25**	**0.66***	**0.68***	▪

DISCUSSION

The main results of this study shows that measures of relative PF, relative isoF and finger hang were highly correlated to climbing performance. In contrast to common strength tests for sport climbers, these are all short-time tests, which gives a more valid measure on maximal peak strength. Hand grip, which used to be a common strength test for climbers, was not correlated with climbing performance. These findings indicates that relative PF, RFD and relative isoF are valid tests for predicting climbing performance and should be included in a test battery for sports climbers. These preliminary results are based on one group with climbers in different performance level groups. We are now gathering data on a bigger sample that will allow us to do sub-analyses for the four different performance levels. These results will add useful knowledge to the climbing research field.

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Recovery during intermittent testing of finger flexor strength in rock climbers – a predictor of climbing ability?

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Summary **Shaking the hand near the body during intermittent contractions is a more effective method of recovery compared to maintaining the recovering hand over the hold. This occurs because the action induces higher muscle re-oxygenation and increases the overall time of the test in rock climbers. The amount of muscle re-oxygenation is related more to climbing disciplines rather than climbing ability. A new diagnostic parameter "aerobic index" based on the effect of recovery is introduced. The index provides a simple way to assess local aerobic capacity of the forearms which is suitable for evaluating the effectiveness of local endurance training programmes as well as distinguishing ability group differences.**

INTRODUCTION

Whilst ascending a route, climbers naturally shake their hands close to their body to enhance recovery of the forearms. However, during intermittent tests, the hand and the arm are fixed in the same position. Placing a hand by the climber's side and shaking is likely to increase micro and macro vascular blood flow and consequently increase the delivery and perfusion of oxy-haemoglobin to the muscle tissue. This study aimed to evaluate the effect of hand shaking during recovery phases of intermittent testing on time–force characteristics of performance and muscle oxygenation.

METHODS

Twenty-two participants undertook three finger flexor endurance tests at 60% of their maximal voluntary contraction until failure. Performances of a sustained contraction and two intermittent contractions, each with different recovery strategies, were analysed by time-force parameters and near infrared spectroscopy.

RESULTS

Recovery with shaking of the forearm beside the body, led to a significantly greater intermittent test time (↑ 22%, $P < 0.05$), force-time integral (↑ 28%, $P < 0.05$) and faster muscle re-oxygenation (↑ 32%, $P < 0.05$), when compared to the hand over hold condition. Further, the ratio of intermittent to continuous test time distinguished specific aerobic muscular adaptations among sport climbers (2.02), boulderers (1.74) and lower grade climbers (1.25).

Table I. Time of contraction in the continuous, shaking and non-shaking intermittent tests (mean ± standard deviation). Values in italics indicate tests' results for climbing ability subgroups.

	Participants	Continuous	Shaking	Non-shaking
Total actual contraction time (s)	*LG (N = 5)*	*60.2 ± 23.0*	*75.4 ± 42.3*	*72.6 ± 33.8*
	SC (N = 11)	*65.9 ± 9.9*	*133.2 ± 45.8*	*99.4 ± 30.9*
	BC (N = 6)	*48.1 ± 9.8*	*83.8 ± 32.1*	*67.3 ± 24.6*
	Total (N = 22)	59.8 ± 115.1	104.9 ± 48.5	86.2 ± 33.2

DISCUSSION

Shaking of the hand near the body (active recovery condition) was found to be a more effective recovery method than keeping the hand above the head. Its effectiveness may be connected with higher vasodilative responses and increased blood flow, as the forearm is placed under the level of the heart [1]. Shaking of the hand near the body increased re-oxygenation by ~ 32%, in comparison to the non-shaking condition. Moreover, the amount of re-oxygenation was not related to climbing performance but rather to climbing disciplines.

As the intermittent contraction times are longer than those seen during the sustained contractions (at the same 60% of MVC), the additional energy required must have been derived from the aerobic metabolism. In the current study the mean "aerobic index" in sport climbers was 2.02 (+ 102%, in comparison to the time of continuous test), which was substantially higher than both boulderers (1.74) and lower grade climbers (1.25). This suggests that sport climbers have a higher aerobic capacity in the forearm flexors, and this is likely a result of discipline specific training adaptations as it is greater than that seen in the boulderers. A further interesting finding was that the "aerobic index" was significantly related to the degree of re-oxygenation, confirming higher use of oxygen in advanced and elite sport climbers during recovery periods between intermittent contractions.

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The effect of cold ambient temperatures on climbing-specific finger flexor performance

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***Summary* – The effect of cold (10°C) and neutral (24°C) ambient temperatures on finger flexor performance was examined in twelve rock climbers. After sitting at rest for 30 min in the designated temperature condition, participants completed maximal voluntary contractions (MVC) on a climbing-specific finger flexor assessment device equipped with a crimp grip. Participants then completed a fatiguing intermittent contraction task until failure. Maximal voluntary contractions recovery was assessed immediately, 5, 10, and 15 min post task failure. The results showed no significant difference between MVC strength between conditions. Time to task failure was significantly longer during the cold condition (364 ± 135 vs 251 ± 97 s).**

INTRODUCTION

Rock climbing is an indoor and outdoor sport that is performed in a wide range of ambient temperatures. This exposure occurs not only while climbing, but also while resting between climbs, and during the approach to a climbing destination. Although it is known that cold temperatures can positively or negatively affect muscular performance based on the specific temperature and method of cooling [1], these effects have yet to be examined in rock climbing. Given the importance of the finger flexors in rock climbing [2, 3], the current study examined the effects of cold ambient temperatures on climbing-specific finger flexor performance.

METHODS

Twelve college aged (21.1 ± 2.8) rock climbers (8 males), average of 5.10c redpoint grade level based on the Yosemite Decimal System, participated in this study. A counterbalanced repeated measures design was used in which participants each completed two conditions separated by an interval of 1 week. The control condition consisted of thermoneutral air that was maintained at 24 ± .38 °C. During the cold condition, the lab was maintained at 10 ± .64 °C. Participants were dressed in shorts, a T-shirt, and shoes for both sessions and were required to sit motionless for 30 min before beginning the protocol. Participants were set up and secured into a chair in order to prevent any contribution of muscular forces other than the finger flexors. The chair and participants were adjusted so that their shoulder was abducted and externally rotated to 90°, their elbow was flexed to 90°, and the shoulder was horizontally adducted to 60°.

After 30 minutes of rest, participants completed 3 baseline MVC of the finger flexors separated by 1 min of rest. Assessment of MVC was conducted on a custom built device instrumented with a load cell (SMA-600N, Interface, Scottsdale, Arizona) and a crimp grip. Force data was recorded at 1000 Hz with Spike 2 (CED, Cambridge, England) and displayed on a 1.77 m monitor (Sharp, Mahwah, NJ) in front of the participant. After 5 min of recovery, participants then began an intermittent fatiguing protocol consisting of 10 s contractions at 40% of their MVC followed by 3 s of rest until failure. Failure was defined as not being able to maintain -5% of the 40% MVC for 2 consecutive s. Recovery of MVC were assessed immediately after, 5, 10, and 15 min post task failure. A repeated measures ANOVA was used to analyze MVC strength throughout testing and between conditions. A paired sample t-test was used to analyze time to task failure. Statistical significance was set at $p < 0.05$.

RESULTS

The results of this study showed that MVC force was similar between conditions at baseline and throughout testing. There was no significant interaction (time × condition). However, time to task failure was significantly longer in the cold condition (364 ± 135 vs 251 ± 97 s).

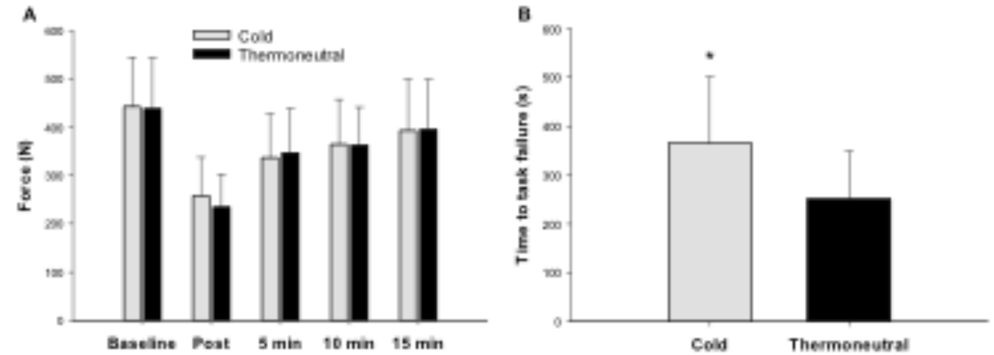

Figure 1. **A** MVC strength at baseline and throughout recovery **B** Time till task failure (*p < 0.05)

DISCUSSION

The main finding of this study was, despite no significant difference between conditions in finger flexor MVC strength at baseline and throughout recovery, time to failure during the fatiguing task was significantly longer in the cold condition. These findings are important for researchers and climbers when considering testing conditions and optimizing performance, respectively.

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The effects of long term sport rock climbing training on heart rate variability in sedentary adults

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***Summary* – The purpose of the study was to investigate the effects of sport rock climbing (SRC) on heart rate variability (HRV) after eight weeks of training. The participants did climbing using top-rope method three times per week for 8 weeks, 60 minutes per session, at the level of 70 % of the maximum heart rate. According to the findings, an improvement was seen in some HRV parameters. However, it can be concluded that an exercise program based on SRC should be made more than eight weeks in order to have statistically significant changes with the purpose of the observing an improvement in heart functions.**

INTRODUCTION

Heart rate variability is used in the sports sciences as it shows the magnitude and time between consecutive heart beats [1] and is a non-invasive method to evaluate autonomous heart functions [2]. In exercise and the sports sciences, it is used to examine the acute effect of physical activity and the chronic effects of exercise on the heart [3]. The purpose of this research was to determine whether an eight-week SRC training period causes a chronic change in heart functions. This will allow a better understanding of how SRC affects heart health.

METHODS

The participants were divided into two groups as control (CG, n=10) and experimental group (EG, n=9). While the EG went and did climbing training by using the top-rope method on a 12-m indoor artificial climbing wall for 60 minutes a day, three days a week for 8 weeks at the level of 70 % of the maximum heart rate, CG didn't take part in any regular physical activity during the study. After taking aerobic power measurements by using Bruce treadmill test protocol, target heart rates were determined by using the HRreserve method for each subject. A dynamic rhythm ECG record was taken using a Biomedical branded VX3 Digital ECG Recorder (CA, USA) during 24 hours. By using the measurements made with the device; total HR (HRtot), average HR (HRave), minimum HR (HRmin), maximum HR (HRmax) and some additional HRV parameters (SDNN, SDANN, PNN50, RMSSD, TRIA) could be obtained. All subjects received pre-and post-test measurements of HRV for the 4 days prior to the start of the climbing exercises and immediately after the end of the 8-week test period. The normal distribution parametric was subjected to a Paired Sample t-Test, and the nonparametric distribution was given a Wilcoxon test. An alpha value of 0.05 was accepted for all of the statistical analyses.

RESULTS

According to the results, no significant differences were found in the HRV parameters' pre- and post-tests average. However, in some HRV parameters for the experimental group, improvements showing a decrease in sympathetic effect and an increase in parasympathetic activity were observed. The decrease of HRave and the increase of time-domain (SDNN, SDANN, PNN50, and RMSSD) parameters show the increase of parasympathetic activity.

Parameters	Pre test	Post test	*p* value
Control Group			
HRtot	99499.60 ± 15094.74	100296.30 ± 16528.32	0.859
HRmax	167.70 ± 41.12	177.70 ± 34.95	0.114
HRave	75.10 ± 8.22	75.30 ± 8.24	0.719
HRmin	43.90 ± 6.15	44.80 ± 6.17	0.475
SDNN	180.50 ± 28.62	189.30 ± 35.05	0.439
SDANN	91.90 ± 29.30	79.40 ± 16.52	0.415
PNN50	27.70 ± 8.74	24.10 ± 8.35	0.106
RMSSD	66.70 ± 25.28	64.00 ± 17.23	0.721
TRIA	792.80 ± 151.42	794.50 ± 165.03	0.976
Experimental Group			
HRtot	91173.56 ± 13519.90	94301.89 ± 14166.33	0.449
HRmax	156.56 ± 23.70	159.11 ± 19.14	0.788
HRave	70.11 ± 9.64	67.00 ± 10.76	0.369
HRmin	42.33 ± 6.65	41.67 ± 6.96	0.833
SDNN	203.77 ± 37.44	215.00 ± 51.71	0.607
SDANN	94.11 ± 30.33	104.56 ± 34.81	0.411
PNN50	29.67 ± 12.65	34.89 ± 15.25	0.406
RMSSD	73.00 ± 26.04	78.22 ± 34.26	0.638
TRIA	899.00 ± 237.17	841.67 ± 234.98	0.542

DISCUSSION

It is known that regular physical activity has many positive effects on health protection and development. These positive effects depend on the duration, frequency and intensity as well as the type of the activity. According to the results obtained from this study, exercise experts should plan programs which are longer than eight weeks in order to see significant changes if they intend to use sport rock climbing as the main activity in exercise programs that target functional changes in the heart. The same research can be carried out by creating a second experimental group undergoing an aerobic exercise program which will be accepted as a standard in some studies. Thus, chronic adaptations that occur as a result of SRC can be compared with other types of activities in a more accurate and simultaneous manner.

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Heart Rate, Perceived Effort, and Anxiety during Top Rope & Lead Rock Climbing

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Summary **– Intermediate level climbing participants (n = 10) performed a repeated measures ascent of top rope (TR) and lead (LD) routes on an indoor climbing wall. Heart rate (HR) was continuously monitored and perceived effort (PE) assessed immediately post climb. The Competitive State Anxiety Inventory (CSAI-2) was completed immediately prior to each climb. Minimum and average HRs were significantly greater for LD with no difference between HRmax or PE despite significantly greater time to complete the route on LD. Cognitive and somatic anxiety in addition to self-confidence were not significantly different between conditions. Ultimately, a greater cardiac and enhanced sympathetic nervous system mediated response (i.e., metaboreflex) with greater min and average HRs were apparent during LD, illustrating the specificity of physical overload on LD when compared to TR.**

INTRODUCTION

Climbing involves episodes of isometric holding[1] and both aerobic and anaerobic energy system involvement[4]. Moreover, as metabolites accumulate in climbing specific skeletal musculature with overload, such as during TR or LD ascents, localized muscle vasodilation occurs and blood flow is directed to this area via increased cardiac output and blood flow redistribution[7]. Henceforth, this implies specific feedback to the Central Nervous System (CNS) via the metaboreflex[6], which consequently invokes a rise in sympathetic activation and increased heart rate (HR)[5,6] along with possibly increased perceived effort (PE). Some researchers have explored the psycho-physiological impact of TR vs LD ascents[3]. Moreover, it has been reported that LD, especially during an on-sight attempt, influences a climber's stress and therefore their physiology or response to climbing[2], most likely to a greater extent vs. TR ascents. Knowing this and using a repeated measures design, we investigated HR, PE, and state anxiety changes during TR and LD conditions in experienced rock climbers. We hypothesized LD would increase psycho-physiological overload.

METHODS

Intermediate rock climbers (n = 10, males = 8; best lead climb range in past 6-mo = 5.10a – 5.11c), in a repeated measures format climbed the same indoor, 11 meter high route (independently rated by several climbers as a 5.9 on the YDS) on TR first, followed by LD with ~8-min of rest in between each condition. Climbers, already familiar with the indoor climbing terrain, were told to cover the route as quickly as possible. A Polar RC3 GPS® watch and chest strap (Polar Electro, Kempele, Finland) were worn during climbs and continuously recorded HR. Immediately pre-ascent, climbers completed the CSAI-2 and instantly post-ascent, climbers were asked their PE on a 6 to 20 scale (6 = no exertion, 20 = max exertion). Lastly, during each climbing condition, an independent evaluator recorded time of ascent. Multiple paired, one tail t-tests were utilized and a Bonferroni adjustment employed; therefore, significance was set at $p < 0.01$.

RESULTS

Height, weight, age, and ape index are reported in Table 1, below. Average time of ascent (ToA) was significantly greater (p=.004) on LD and is presented in Figure 1. Individual ToA's are given in Figure 2. Figure 3 represents HR minimum, mean, and max values. Significant differences were found between conditions related to minimum (p=.007) and mean (p=.001), but not maximum HR's (p=.021). No significant difference (p=.56) for PE was observed between conditions. Lastly, no significant differences in cognitive and somatic anxiety along with self-confidence were calculated ($p > 0.01$) and are reported in Table 2.

DISCUSSION

The primary results of this study indicated a greater minimum and mean HR during LD along with a greater time of ascent on LD. No difference in PE was observed. Therefore, despite a possible greater metaboreflex and sympathetic nervous system arousal while on LD, as indicated by greater minimum and mean HRs vs. TR, the climbers did not perceive LD as "harder", supporting only part of our hypothesis. However, if a climber's goal is to get better on LD, they should attempt to duplicate specific psycho-physiological overload related to their climbing goal.

Table 1. Participant Characteristics.

	APE Index (cm)	HT (cm)	WT (kg)	Age (yrs)
Mean	172.8	171.1	66.0	27.4
SD	8.5	5.2	5.3	12.5

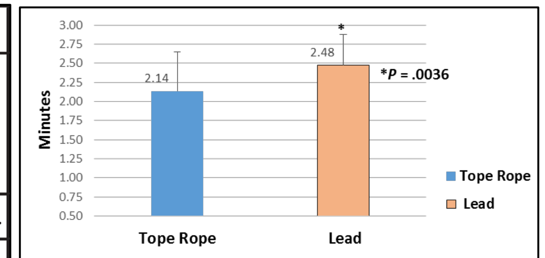

Figure 1. Average time of ascent. *Denotes significant difference vs. TR.

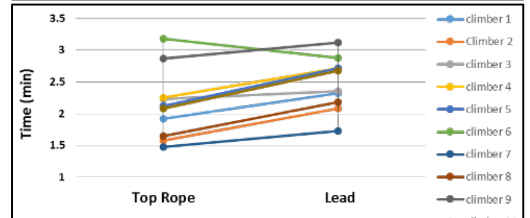

Figure 2. Individual climber time of ascent on TR and LD.

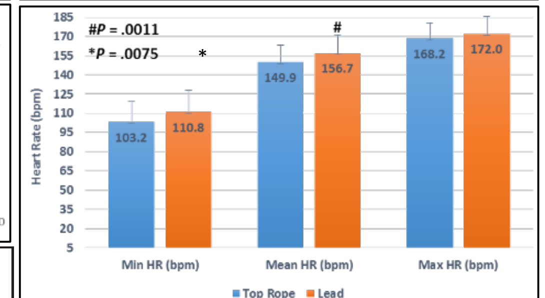

Figure 3. Minimum, mean, and max HR response to TR vs LD climbing.

Table 2. Competitive State Anxiety Inventory (CSAI-2) for tope rope & lead climbs (mean±SD; n = 8).

	TR Climb	LD Climb
Cognitive anxiety	13.0±1.7	14.9±3.0
Somatic anxiety	15.1±2.2	16.9±2.7
Self-confidence	29.9±4.3	28.1±5.0

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Effect of hypohydration on climbing to failure on a treadwall

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***Summary* – The effect of hypohydration on climbing performance, determined by climb time to failure, was studied with eight male climbers who had at least one year of climbing experience. Physiological parameters were examined as well. Subjects took part in two randomly assigned climbing sessions, one in a euhydrated state and the other in a hypohydrated state. Hydration level was determined by specific gravity of urine (U_{sg}). Climbs took place on a treadwall with a 10 degree overhang. Subjects were asked to climb as long as they could. Climb time started the second climbers got onto the wall and ended when they came off. While not significant, the mean climb time for euhydrated subjects was slightly longer than hypohydrated subjects and the mean $\dot{V}O_2$ for climbs was slightly higher as well for euhydrated subjects.**

INTRODUCTION

The process of dehydration leading to a hypohydrated state affects many physiological parameters in the human body [1]. Many studies have documented the negative effects hypohydration has on endurance performance with mixed results reported for strength and power activities [2]. The physiological demands of rock climbing tend to differ some from the typical progression produced by running and cycling tests [3]. The purpose of this study was to understand the effect hypohydration had on climbing time to failure on a treadwall.

METHODS

Two climbing sessions took place on a treadwall with a 10 degree overhang. Each subject was randomly assigned to a different state of hydration, euhydration or hypohydration, for each session. Hydration level was measured using an AimStrip® urine reagent strip (Germaine Laboratories, Inc, San Antonio, TX) . A euhydrated state was defined as a U_{sg} less than 1.020 and a hypohydrated state was defined as a U_{sg} of 1.020 or higher. Climb time, $\dot{V}O_2$, and heart rate were recorded using a Cosmed K4 b^2 (Rome, Italy) for baseline data and through the entire climbing session. Blood pressure and rate of perceived exertion (RPE) were measured at baseline and immediately following the climb with an e-sphyg 2 Automated Sphygmomanometer (ADC, Hauppauge, NY) and the Borg Scale [4]. Nine male subjects with at least one year of climbing experience (10.94 ± 6.36 yrs), between the age of 18 and 45 (35.33 ± 6.36 yrs), volunteered for this study. Subjects were allowed a 5 minute warm up on a climbing wall. For the climbing session subjects were asked to climb until failure on the treadwall. Two 2x2 repeated measures ANOVAs and three t-tests were used to analyze the data. Effect sizes, Cohen's d, were also computed.

RESULTS

Three paired-sample t-tests were computed to compare climb time, mean $\dot{V}O_2$, and RER during different states of hydration (euhydration and hypohydration). No significant differences were

determined for climb time, mean $\dot{V}O_2$, or RER ($p > .05$). However, a small to medium effect size (d = .37) was found for climb time between the euhydrated state (780.22 ± 981.71 sec) and the hypohydrated state (680.67 ± 755.30 sec); and a medium effect size (d = .53) was determined for mean $\dot{V}O_2$ between the euhydrated state (32.62 ±3.54 ml/min/kg) and the hypohydrated state (30.99 ± 2.99 ml/min/kg). Based on the ANOVAs, no significant differences were found in heart rate (resting and peak), and blood pressure (resting and post climb) in the euhydrated state or the hypohydrated state ($p > .05$).

DISCUSSION

The main findings of this study were the effect sizes found for climb time and $\dot{V}O_2$. There were no statistically significant differences in any of the dependent variables, however euhydrated subjects had a longer climb time and higher mean $\dot{V}O_2$ than hypohydrated subjects. Based on the effect size, the lack of significance in these measures was most likely due to the small number of subjects this study had. Based on these findings, performance and intensity of a climb could be negatively impacted by a hypohydrated state.

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Evaluating the Rock Prodigy Training Method

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Summary **– The Rock Climber's Training Manual describes a linear-periodic training method that has anecdotally shown continuous long-term improvement in some climbers. Here, the method is evaluated across a larger population and shown to be very effective at improving finger strength (32% increase) and climbing performance (+2.5 YDS letter grades) after training.**

INTRODUCTION

In 2014, The Rock Climber's Training Manual: *A Guide to Continuous Improvement* [5] was published, presenting a training methodology for rock climbers that is based on sports science. This Rock Prodigy Method (RPM) uses linear periodization through a variety of exercises. In this paper, the efficacy of the RPM is evaluated by comparing pre- and post-training performance. Performance is quantified in terms of both finger strength and overall climbing performance.

PURPOSE

Climbers commonly experience initial improvement in their first years in the sport, followed by long, performance plateaus. In one study, climbing ability did not correlate with years of climbing experience, frequency of climbing or training, or use of a systematic training program [6]. This may be evidence of the general lack of effective training protocols and tools, and/or lack of willingness of climbers to adhere to a training program. With the Rock Climber's Training Manual, the authors sought to provide a methodology that is based on sports science research, has a proven record of producing long-term improvement and is easy to follow. The resulting Rock Prodigy Method is based on 18 years of personal experimentation by the authors and coaching others; all of whom experienced long-term climbing improvement. There are numerous climbing training regimens available, but evidence of long-term improvement is severely lacking, and is the most important metric for judging a training program.

METHODS

The RPM uses linear periodization to build finger strength and overall climbing fitness over a roughly 12 week training cycle, resulting in a performance peak lasting 4 – 8 weeks. These training phases are Base Fitness, Strength, Power, and Power Endurance (**Error! Reference source not found.**). A major focus of the RPM is finger strength training on a hangboard, which is responsible for long-term improvement over years of training and is well correlated with climbing performance [1]-[4]. The Base

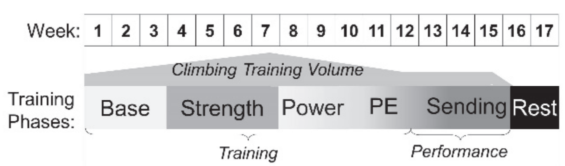

Figure 1 Example RPM training cycle which uses linear periodization with four distinct training phases.

Fitness phase consists of anaerobic threshold training [7][7]. The Power phase consists of high intensity, dynamic exercises such as Limit Bouldering and Campusing. The Power Endurance phase consists of moderate to high intensity interval training. The reader is encouraged to consult the Manual for more details.

The effectiveness of the RPM was evaluated by collecting performance data from 118 climbers through an online survey on the author's website [8].

Table 1 RPM climbing performance improvements in units of YDS letter grades. All means passed the paired two sample t-test and are statistically significant at the 0.0001 level.

Mean Increase in Hardest Climb Rating:				Qualitative Assessment:		
1st Season		All Seasons		*How has the RPM changed your performance?*		
Redpoint	Onsight	Redpoint	Onsight	No Change	Slightly Improved	Significantly Improved
1.44	1.51	2.50	2.03	4.7%	38.3%	57.0%

RESULTS

69% of respondents indicated they followed 75% or more of the prescribed RPM workouts. Finger strength was quantified by *weight hanging ability* (WHA – body weight plus/minus any added/subtracted weight). All respondents experienced significant increases in finger strength with a mean gain of 26.1 lbs per grip (N = 158 grips) after one RPM training season and 38.3 lbs per grip (N = 73 grips) after multiple RPM seasons (21.5% and 32.0% increases, respectively).

On-rock climbing improvement was remarkable for climbers and is summarized for all respondents in Table **1**. The respondents' pre-training demographic data weakly correlated climbing ability to experience, showing a meager rise of one YDS letter-grade per decade in the sport. However, with the RPM, significant improvement occurred for these same climbers after only one season of training.

DISCUSSION

In addition to the quantifiers, 95.3% of respondents indicated they had otherwise improved, such as climbing a personal-best route in less time or fewer tries, or climbing several such routes in one season. It is likely that the RPM was effective because it is easy-to-follow and is accompanied by evidence of its effectiveness that motivated users to adhere to it. Therefore, the subjects were relatively undertrained, and had high potential to improve with training.

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Finger Strength Improvements with the Rock Prodigy Training Center Hangboard

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Summary – The development of the Rock Prodigy Training Center (RPTC) hangboard is described, along with an evaluation of its effectiveness at improving finger strength. A 118-climber survey indicated that training on the RPTC increased finger strength 32% and red point ability by 1.35 YDS letter grades.

INTRODUCTION

The Rock Prodigy Training Center (RPTC) is a novel hangboard designed for elite finger strength training [1]. Research indicates sport-specific finger strength is a substantial contributor to climbing performance [2]-[5]**Error! Reference source not found.**. Here, the RPTC is evaluated by comparing pre- and post-training performance of climbers which is quantified in terms of finger force production and overall climbing performance.

Traditional hangboards may be designed for marketability rather than finger strength training and they often lead to overuse injuries [8]. This may be due to the single piece, symmetric hangboard design which can force the athlete's hands too close together or apart while using certain grips. Skin injuries are also very common with hangboards and can greatly impede training. Finally, hangboards are usually hand-shaped, so they are not highly repeatable, nor easily refined.

PURPOSE

Here we sought to create a training tool that improves finger strength, improves climbing performance and is more ergonomic than other hangboards. We hypothesize that better ergonomics will enable better, higher-intensity training without injury. The design goals were to: 1) increase ergonomics, 2) reduce skin stress, 3) reduce unused material and 4) increase specificity to rock holds.

METHODS

The iterative design process included biometric analysis, 3D computer modeling, rapid prototyping, and testing to refine hold configurations and shapes. Finally, a computer-aided manufacturing process was used to ensure accurate reproduction. The RPTC's innovations include: (a) 2-piece design for adjustable hand spacing and rotation, (b) angled grips that track arm rotation and improve upper body ergonomics, (c) progressive difficulty grips, and (d) rotated, ergonomic pinches.

The RPTC was evaluated from the training data of 118 users. The training consisted of several sets of static two-arm "dead-hangs" that follow a premeditated sequence of grips [6]. The intensity can be increased or decreased by hanging supplemental weights from a harness or by attaching a weighted pulley system that assists the athlete. This weight is also used to quantify the athlete's finger strength.

Respondents recorded their *weight hanging ability* (WHA – their body weight plus/minus any added/subtracted weight) on specific grips during training, as well as their personal best climbs before and after training.

RESULTS

All respondents experienced significant increases in WHA, and thus, finger strength for all grips that were trained. The mean finger strength gain across all respondents and grips was 26.1 lbs (*N = 158 grips*) after one, 4-week training phase (totaling 8-10 workouts) and 38.3 lbs (*N = 73 grips*) after multiple phases.

These are 21.5% and 32.0% increases in finger strength, respectively. Next, improvements in overall Red Point (RP) and On Sight (OS) climbing performance were examined in the 4-6 weeks after training (**Table 1**), with an average 1.35 letter grade improvement after the first season training on the RPTC.

Table 1 Climbing performance improvements as a result RPTC training in units of YDS letter grades.

Mean Increase in Hardest Climb Rating:				Qualitative Assessment:		
1st Season		All Seasons		*How has the RPTC changed your performance?*		
Redpoint	Onsight	Redpoint	Onsight	No Change	Slightly Improved	Significantly Improved
1.35	1.29	1.96	1.72	7.7%	41.5%	50.8%

DISCUSSION

Respondents also indicated improvement qualitatively, which is helpful in rock climbing because improvement from training may not result in immediately climbing a new personal best route in that season. After using the RPTC, 92.3% of respondents indicated they had improved in some way. 85% of respondents were able to train harder without *fear of injury* versus other training methods (64% versus *other hangboards*). 74% of users *incurred fewer injuries* than other training methods (24% were "not sure") and 53% had fewer injuries versus other hangboards (37% not sure).

The RPTC is effective at improving finger strength and climbing ability in rock climbers. Data indicates that the 2-piece design and other features are more ergonomic, allowing harder training and improved performance – the most important metric for climbers. Longer-term effects will be studied in future work.

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Comparison of the Effects of Three Hangboard Training Programs on Maximal Finger Strength in Rock Climbers.

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***Summary* – The effect of three dead-hang training programs, each comprising two 4-week cycles, over strength improvement measured by maximum added weight borne while hanging off a 15 mm edge, was studied in three groups of sport climbers with a sport level of 7c+/8a. The group that performed lower-volume sessions of maximal repetitions with complete pauses (n=11) experienced greater improvement than the group doing a medium-volume of submaximal dead-hangs with incomplete rest (n=8) and the group that combined both methods (n=7).**

INTRODUCTION

Climbing requires a high level of finger strength to maintain the grip on handholds. Hanging off the fingertips is the method most frequently used by climbers to develop grip strength. When prescribing a training program, the volume, intensity and recovery variables are determinant for its effects. Traditionally there have been two methods that climbers used: one based on low volume, high intensity and complete pauses, and other, commonly known as "repeaters" with moderate to high volume, submaximal intensity and incomplete recovery. Despite their popularity, no scientific study had compared the effects of both methods over strength development to this date.

PURPOSE

Comparing the effect on strength development of three dead-hangs training programs, comprised of two 4-week phases each: group 1 used low volume, maximal loads and complete pauses (LvMax-LvMax), group 2 employed medium volume, submaximal loads and incomplete pauses (MvSub-MvSub) and group 3 combined both methods (LvMax-MvSub).

METHODS

The hangboard with adjustable wooden edge described and validated by López-Rivera & González-Badillo (2012) [1] was used for both dead hang training and finger strength testing. The finger strength test (ST) consisted in hanging off a 15-mm deep edge for 5 seconds with maximum added weight. Once the initial strength test was completed (ST1), twenty six climbers (average of French 7c+/8a redpoint level, 31.7 years old and 11.7 years of climbing experience) were randomly assigned to one of three training groups: the LvMax-LvMax group used the most effective program in terms of maximal strength in the previously cited study [1], 8 weeks doing 3-5 sets of 10-second maximal dead-hangs with 3-minute pauses between them. The MvSub-MvSub group spent the two 4-week cycles performing 3-5 sets of 4 to 5 10-second repetitions each, resting 5 seconds between repetitions and 1 minute between sets. The LvMax-MvSub group used the former method in phase one and the latter in phase two. On weeks 4 and 8, ST2 and ST3 were carried out respectively. Repeated measure ANOVA and the magnitude-based inference [2] were used to analyze the data.

RESULTS

No significant differences in strength were found among groups prior to training. Although no statistical significance was reached in strength gains among groups at ST2 and ST3 compared to ST1, magnitude-based inferences revealed that LvMax is possibly beneficial (51 % and 71 %, for group 1 and 3 respectively) compared to MvSub after 4 weeks of training. Furthermore, LvMax-LvMax is possibly beneficial compared to LvMax-MvSub (58%) and to MvSub-MvSub (60%). Lastly, LvMax-MvSub lost at ST3 6 % of the gains obtained at ST2.

Table I. Strength results by group (kg, mean ± s)

	LvMax- LvMax group (n = 11)			MvSub-MvSub (n = 8)			LvMax-MvSub (n = 7)		
		%	ES		%	ES		%	ES
ST1	30,00 ± 11,67			33,75 ± 13,43			34,64 ± 14,68		
ST2	34,55 ± 9,21	15,2	0,4	35,31 ± 10,73	4,6	0,1	41,79 ± 14,34	20,6	0,5
ST3	38,41 ± 9,17 [a]	28	0,7	38,44 ± 11,64	13,9	0,3	39,29 ± 12,22	13,4	0,3

Differences among groups not significant ($p > 0.05$).
[a] Intra-group significant differences compared to ST1 ($p < 0.05$).

DISCUSSION

This study's main result was the greater strength development observed with the LvMax-LvMax method, probably due to neural adaptations linked to the use of high intensities [3]. It is worth noting that MvSub-MvSub gains peaked after 8 weeks of training, probably via hypertrophy promoted by the combination of higher volume per set, submaximal intensity and shorter pauses between repetitions [4]. These results suggest that the most beneficial method for grip strength in climbing is LvMax-LvMax, but a medium-term planning could benefit from sequentially prescribing LvMax-LvMax and MvSub-MvSub so that the effects of hypertrophy add up to the neural ones.

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Effect of maximal- and local muscular endurance strength training on climbing performance and climbing-specific strength in recreational climbers: a randomized controlled trial

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Introduction

The value of traditional strength training is debated among experienced climbers because of the lack of specificity (Hörst, 2008). But if large parts of climbing performance can be explained by simple tests (i.e. finger strength/endurance and bent-arm hang), then it is possible that strength training including relevant muscles will have a positive effect on climbing performance in lower skill levelled climbers.

Purpose

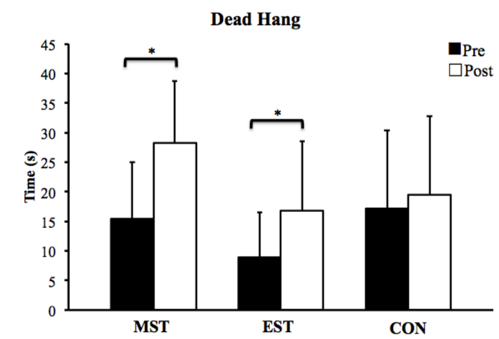
Therefore, the aim of the study was to investigate the effect of maximal strength training (5 RM x 4) compared to local muscular endurance (20 RM x 2) in a climbing performance test, two climbing-specific strength tests and a general strength test. It was hypothesized that both training protocols would improve performance in the climbing performance test and in climbing-specific strength tests, but the maximal strength training group would have a better effect than the local muscular endurance training group.

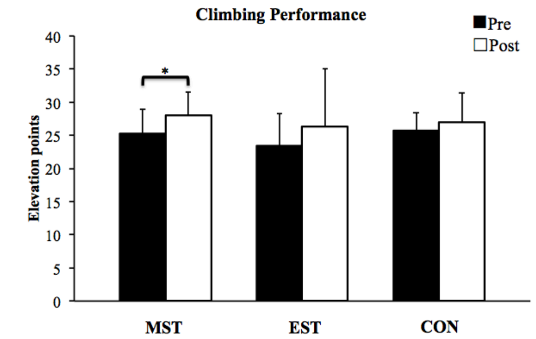
Methods

Thirty-one recreational climbers (age 23.6 ± 2.2 yr, height 174.9 ± 8.7 cm, weight 69.8 ± 11.4 kg, climbing experience 3.2 ± 2.3 yr) with best on-sight performance between 4b and 6b (French grade) participated in a twice-a-week strength training programme for 10-weeks. Participants were randomized into three groups: 1) maximal strength training (MST, n = 10), 2) local muscular endurance training (EST, n = 11) and a control group (CON, n=10). The CON group continued climbing/training as usual. Before and after the intervention, all the participants were tested in climbing performance, in climbing-specific strength and in a 12 RM pull-down test.

Results

The results revealed a significant 10.9% improvement for the MST group ($P < 0.05$), but not for the EST or CON ($P > 0.05$) in the CP test. Further, the MST and EST groups increased 86.7% and 87.5% in dead hang (DH), 46.5% and 37.7% in bent-arm hang (BAH) and 17.4% and 15.5% in 12 RM pull-down ($P < 0.05$), respectively. In BAH, the CON group increased 14.3% ($P < 0.05$). No differences were observed between groups in post-results or in percentage improvements from pretest in the CP, DH and BAH tests. However, a greater percentage improvement between the training groups and CON was observed in the 12 RM pull-down test ($P \leq 0.001$), but not between the MST and EST ($P = 1.00$).





Discussion

CP and strength increase: In line with the hypothesis, the MST group improved their climbing performance in contrast to the EST and CON groups. However, no difference in absolute values or percentage improvements was observed between the groups. The results from the present CP test are not comparable to previous research, because no other studies to our knowledge have examined climbing performance on a custom-designed climbing route after a strength training intervention.

Climbing-specific strength: The dead hang test measures the participants' finger endurance in relation to their body weight, which is an important factor in climbing performance (Baláš et al., 2012; Grant et al., 1996; Watts et al., 1993). Both maximal strength and local muscular endurance training groups improved their dead hang time from pre- to post-test.

In conclusion, maximal strength training improved climbing performance for recreational climbers. Further, both maximal strength and local muscular endurance training programmes improved in climbing specific strength tests, but none of the approaches demonstrated greater advantage than the other.

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The influence of low-friction quickdraws on impact forces in climbing falls

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Summary **– The influence of low-friction carabiners (LFCs) on maximum impact forces (MIFs) in climbing falls was evaluated in an experimental field study. Three setups with different amounts and degree of rope redirections were installed at a climbing wall and tested with repeated climbing falls. The impact forces were recorded by three load cells, mounted within the belay chain. For all tested situations the results showed an increase of MIF at the belay point, while MIFs decreased at the climber, when using LFCs. The differences in dynamic belay scenarios were higher than in static belay tests.**

INTRODUCTION

Early studies have identified that rope friction at carabiner and rock lead to higher impact forces in climbing falls [1]. Later studies concentrated on finding theoretical numerical approaches to calculate this effect [2, 3]. While some validated their models by experiments in laboratories [2] and proofed the influence of rope friction on maximum impact forces (MIFs), others still neglect this safety relevant aspect in their studies [4]. Quickdraws with low-friction carabiners (LFCs), which might lead to a reduction of MIFs or at least to a different force distribution within the belay chain, entered the marked during the last years. But no scientific study about their effects on impact forces has been published yet. The aim of this study was to evaluate the influences of LFCs on MIFs in climbing falls under real conditions.

METHODS

Three stainless steel tension rods were instrumented with four 350Ω strain gauges (K-LY4-3-05-350, Hottinger Baldwin Messtechnik GmbH, Darmstadt, GER) and wired up with a Wheatstone full bridge, amplified by an instrumentation amplifier (INA 125, Burr-Brown Co., Tucson, AZ) and recorded at 500 Hz with Arduino Leonardo R3 (Arduino Slr., Torino, ITA) micro controller boards. The sensors were interconnected by a wireless ZigBee network (XBee Series2, Digi Interlational Inc., Minnetonka, MN). The evaluation took place at a constantly 15° overhanging artificial climbing wall in a climbing gym. The load cells were installed at the falling mass between climbing harness and knot, at the last anchor instead of the quickdraw sling and at the belay point. In case of static belay, it was placed between the fix point anchor and the belay device (Eddy, Edelrid GmbH & Co. KG, Isny, GER). When dynamic belaying was performed, it was placed between harness of belayer and the belay device. One male climber (76 kg, 1.81m, 15 years climbing experience) performed 120 repetitive falls at three different scenarios. The dynamic belay was performed by a male human (66 kg, 1.74m, 12 years climbing experience). The three tested scenarios had fall factors between 0.22 and 0.23, but differed in the amount and degree of rope redirection (165°, 300° and 410°). Four test series were performed for each scenario. The series differed in belay technique (static and dynamic) and quickdraw type (standard carabiners (SCs) (Micro, Austrialpin GmbH, Fulpmes, AT) and LFCs (Revolver, DMM Ltd., Gwynedd, WAL)). A new rope (Boa

9.8, Edelrid GmbH & Co. KG, Isny, GER)) was used for each series, consisting of ten recorded falls. For data analysis the mean value and standard deviation of the MIFs for each sensor and series were calculated.

RESULTS

For all tested series the MIFs at the belay point increased, but decreased at the climber when using LFCs. While there was a decrease at the last anchor in case of dynamic belay, MIFs increased when using static belay technique and LFCs (see Figure 1).

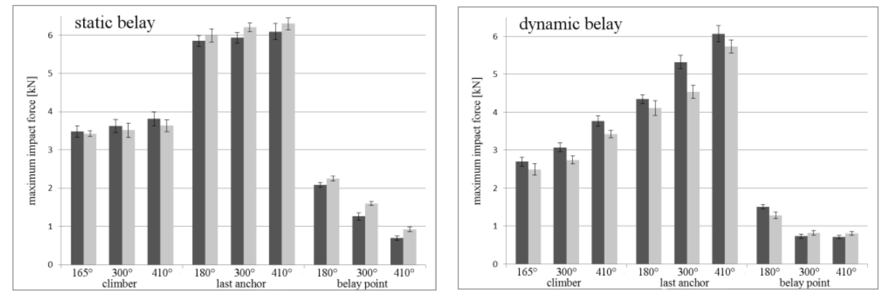

Figure 1 MIFs with standard deviation in static and dynamic belay situations and different degree of rope redirection for a 76 kg climber. SCs in dark grey, LFCs in light grey. Sample size n=10

DISCUSSION

The main results of the study showed that usage of LFCs leads to lower MIFs at the climber and higher MIFs at the belay point. The range of standard deviation overlapped in some cases. The comparison of static and dynamic belay leads to the conclusion, that dynamic elongation of the rope as well as more energy dissipation capability at the belay point lead to this effect. But the differences in MIFs, caused by rope elongation were lower than expected. These findings help to understand the complex behavior of the belay chain in case of large rope friction and could improve safety in climbing.

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Magnesium Carbonate (Chalk) Increases Hang-Time Until Failure in Rock Climbing

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Summary **– The purpose of this study was to assess whether or not chalk affects geometric entropy (GE) or muscular activity during rock climbing. Experienced rock climbers were asked to complete a predesigned bouldering problem, with and without the use of chalk. Following the boulder problem, participants hung from a standard climbing hold until they slipped from the climbing structure. COF and the ratio of the vertical forces on the hand and feet (FR) were determined by a force platform mounted behind the climbing structure. Electromyography ($iEMG_{mean}$) was recorded throughout the trial. Although there were no differences in the COF, GE, FR, or $iEMG_{mean}$, participants were able to hang longer after the use of chalk.**

INTRODUCTION

Rock climbers often attribute the cause of a fall or the failure to complete a route as the inability to maintain contact between the hands and the rock. [1] In an attempt to increase and maintain contact with the rock, climbers often use magnesium carbonate (chalk) on the hands. This substance is meant to increase the static coefficient of friction (COF) between the hands and the rock and presumably dry the hands of sweat. [2-4] The purpose of the current study was to assess whether or not chalk affected GE, or muscle activity during rock climbing. A secondary purpose was to assess any differences in the forces involved in a static hang until failure with or without chalk.

METHODS

Nineteen experienced recreational rock climbers (13 males, 6 females) were recruited from the local climbing community, all habitually used chalk during their climbing pursuits. Participants completed a boulder problem and a static hang, both with and without chalk, on an indoor climbing structure. During the bouldering route foreman electromyography (iEMGmean), geometric entropy (GE) in both the frontal and sagittal plane and climbing time (CT) were assessed. Immediately following the bouldering route, the climber performed a static from a hang board and foot chips fixed to a force plate, (OR6-7-2000 AMTI, Watertown, MA) while hang-time (HT), iEMGmean, COF, the vertical force ratio between the hands and feet (FR) were assessed. Difference between chalk and no chalk conditions were assessed by paired sample T-tests.

RESULTS

There was no significant difference in GE between the chalk and no chalk condition when filmed perpendicular to the climbing surface (P=.359). There was also no significant difference in GE of the climbers when filmed parallel to the climbing surface (P=.440). There was no significant difference in the iEMGmean recorded throughout climbing and static hanging (P=.968). There was also no significant difference in the maximal COF recorded during the hang, with and without chalk, (P=.748). Furthermore, no significant difference in FR with and without chalk (P=.571) was found. A significant difference in hang time (HT) with chalk and without chalk, respectively, was observed: 62.9 ± 36.7 s and 49.3 ± 25.2 s (P=.046)

	Chalk	No Chalk	p
CT (s)	36.9 ± 7.7	38.6 ± 8.0	0.215
GE_{FV}	1.18 ± 0.70	1.17 ± 0.66	0.359
GE_{SV}	1.21 ± 0.13	1.25 ± 0.148	0.44
$iEMG_{mean}$(mV)	0.33 ± 0.45	0.33 ± 0.48	0.968
HT (s)	62.95 ± 36.75	49.30 ± 25.18	0.046
COF_H	0.37 ± 0.12	0.38 ± 0.15	0.748
FR	0.45 ± 0.23	0.47 ± 0.26	0.57

DISCUSSION

Chalk had no significant difference in $iEMG_{mean}$, GE, CT, COF_H or FR. However, these results may be different in more experienced climbing populations and with the addition of a climbing route peaking at the apex of one's experience level. Despite the study limitations, chalk was shown to significantly increase hang time until failure. This is advantageous to the rock climber because it may allow for prolonged rests, and more time to locate ideal holds to plan the next series of climbing moves for optimal route progression.

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Risk taking and ethics in rock climbers

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***Summary* – The question of whether rock climbing is an ethical sport and whether rock climbers act ethically when taking on risk was investigated. One hundred and one rock climbers completed an online questionnaire on sensation seeking and risk taking, and fourteen climbers completed one-on-one interviews to describe their risk taking decision making and behaviors. The results suggest that rock climbers act ethically by carefully considering risks when engaged in the sport, and rock climbing does not lead climbers to pursue risky behaviors elsewhere in their lives.**

INTRODUCTION

A philosophical argument has been made that if the risks one takes in rock climbing leads to a risk taking personality, then rock climbing would be unethical [1]. Additionally, if rock climbers are engaging in risky behavior without proper consideration, then they are behaving unethically. Determining whether rock climbing is ethical is important because as the sport becomes more mainstream, more accidents are reported and awareness grows about the inherent dangers in the sport. If rock climbing is shown to be unethical by its nature, or rock climbers are deemed to be participating in a sport in a generally unethical way, then public perception and support, sponsorship and land access decisions may be affected. The purpose of this study was to examine sensation seeking, risk taking, and ethical considerations in rock climbers through quantitative and qualitative data analysis.

METHODS

Subjects included volunteers 18 and over who self-identified as rock climbers. Subjects were asked to complete an anonymous online questionnaire that consisted of demographic and climbing specific interest items and two previously validated instruments. The Sensation Seeking Scale V (SSSV) [2] is a 40-item Likert scale that measures four sensation seeking subscales: thrill and adventure seeking (TAS), experience seeking (ES), boredom susceptibility (BS), and disinhibition (DIS). The Domain-Specific Risk-Taking Scale (DOSPERT) [3] is a 30-item Likert scale that measures five risk taking subscales: ethical (ETH), financial (FIN), health/safety (HEA), recreation (REC), and social (SOC). The data was analyzed to determine if relationships or differences exist in scores for sensation seeking and risk taking based on demographic variables.

A subset of the sample was asked to participate in a confidential one-on-one interview to discuss risk-taking behavior in the sport of climbing. Questions focused on risk and risk assessment in four types of outdoor rock climbing: bouldering, sport lead, traditional lead, and free-soloing. Interviews were transcribed, coded, and combined with observation notes to analyze for themes.

RESULTS

A total of 101 rock climbers, ages 19 to 71 (*M* age=34.55 yr, *SD* = 11.40) completed the online questionnaire. Subjects included 51 males and 44 females. Self-reported redpoint lead and bouldering skill levels ranged from 5.7 to 5.13c YDS and V0 to V12 respectively. Descriptive analysis of the DOSPERT scale, indicated subjects scored highest in the SOC and REC subscales, followed by HEA, FIN, and ETH subscales. Subjects scored highest on SSSV subscales of ES and TAS. Differences in total SSSV scores were seen in gender and skill level, with males and novice climbers scoring significantly higher ($p \leq 0.05$).

DOSPERT Subscale	Mean (*SD*)	SSSV Subscale	Mean (*SD*)
SOC	35.51 (4.70)	ES	29.21 (4.27)
REC	30.24 (7.41)	TAS	28.36 (5.66)
HEA	20.83 (8.04)	DIS	26.02 (4.63)
FIN	16.11 (5.94)	BS	23.52 (4.28)
ETH	13.60 (4.96)		

A subset of the sample (n=14) participated in the one-on-one interviews. Qualitative analysis showed that overall the subjects assessed multiple areas of risk prior to engaging in outdoor bouldering, sport lead, traditional climbing and free soloing. Themes in risk assessment included physical ability, physical environment, personal and belayer experience/skill level, safety equipment, and mental state. Those individuals who participated in free soloing (n=8) reported engaging in this activity several grades below their redpoint ability. When asked about their rock climbing risk behaviors, the majority (n=9), described no change or being less risky in the sport when compared to the past. All (n=14) subjects described no change or being less risky in areas outside of climbing when compared to the past.

DISCUSSION

The quantitative results showed that subjects did not score high in negative risk behaviors with the exception of recreational risks. Negative risk behaviors were not associated with self-reported skill level or years climbing. The qualitative interviews suggest that climbers take many risk-related factors into consideration before and while engaging in the sport. Both the quantitative and qualitative data suggest that climbers are acting ethically by carefully considering risks within the sport and by not engaging in risky behaviors outside of climbing.

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Anxiety level and ability to climb routes in recreational indoor climbing

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KEYWORDS: anxiety, climbing ability, indoor climbing

Summary

Relationship between anxiety level and ability to climb routes was studied in a group of intermediate climbers. Participants were climbing a specially designed route twice: first attempt using top rope and second attempt leading. After every attempt the level of state anxiety was measured. Both attempts were registered using a digital camera to evaluate climbing techniques. The results showed that several technique elements were rated worse at higher level of state anxiety.

INTRODUCTION

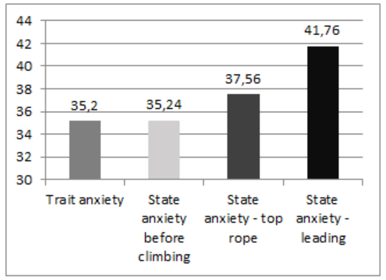
Indoor climbing is a very good example of a sport that stimulates strong emotions. One of the most often felt emotion while climbing is anxiety. It appears as a part of the Brain Defensive System [1]. Movement ability in climbing is expressed with climbing techniques. While climbing a route it determines the objective [2, 3, 4]. Emotions, such as anxiety, can have an effect on achieving the objective. Research on relationship of anxiety and climbing technique, has been tested by several researchers, but never in such wide range [5]. The aim of the study was to find relationship between state anxiety level and indoor climbing ability in different belaying methods.

METHODS

The experiment assumed preparation of a climbing route graded 6b+. The route was set in a manner that allowed two different types of belaying: top rope and leading. The anxiety level was measured using the State-Trait Anxiety Inventory (STAI) [6]. The anxiety level was manipulated using different belaying techniques [7, 8]. To evaluate climbing ability the Climbing Techniques Evaluation Sheet was used [9]. There were two climbing attempts one using top rope and second one leading. Both attempts were recorded using a digital camera. After every attempt the level of state anxiety was measured.

RESULTS

In the study group, average level of trait anxiety was 35.2. Average level of state anxiety before climbing attempt was 35.24, so it was similar to the trait anxiety level. Next test was conducted after climbing, using top rope and leading. The state anxiety level after top rope climbing was 37.56 and after leading 41.76 (fig 1).



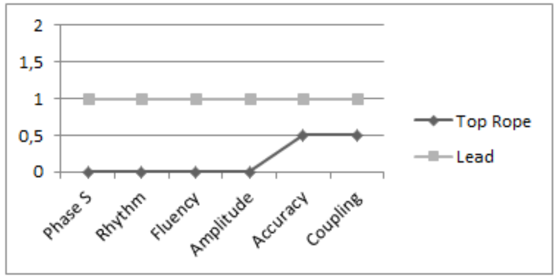


Figure 1 Average level of anxiety of the study group using State Trait Anxiety Inventory.
Figure 2 Average level of penalty points in Climbing Techniques Evaluation Sheet.

The results of the Climbing Techniques Evaluation Sheet show that tested technique elements were rated worse while leading. Average level of penalty points while top roping was 0 or 0.5. Average level of penalty points while leading was 1 in all technique elements (fig 2)

DISCUSSION

The main results of the study show that the level of proper technique performance is reduced while leading the climbing routes. Higher level of state anxiety has an influence on the climbing ability. The influence was observed in such technique elements like phase structure, rhythm, fluency, amplitude, accuracy and coupling. These findings help to understand how emotions, like anxiety, can affect recreational climbing.

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STUDY OF PRACTICAL REASONING IN REGIONAL AND NATIONAL LEVEL CLIMBERS DURING THE ASCENT OF AN UNKNOWN NATURAL BOULDER

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SUMMARY

This study aims to describe the practical reasoning (PR) and the rules, which are mobilized by regional and national level climbers during the ascent of an unknown natural boulder. The theoretical framework of the culturalist anthropology [1]has been chosen to analyze the rules followed by the climbers during their ascent attempts and to characterize PR types. A two-part protocol has been set to collect the data. The climbers have been filmed during their trials(Part 1) then immediately interviewed by self confrontation after their climb in front of the boulder (Part 2).The results helped to identify four types of PR and the difficulties encountered by each climber in relation with the methods used during the ascent. The understanding of these difficulties in relation with the PR, which are mobilized by the climbers, allows a better understanding of the meaning of the "climbing method" ordinary concept and to feed the design of training programs.

Key words: Practical reasoning; Rules; Self confrontation; Climbing method; Training program.

INTRODUCTION AND THEORETICAL FRAMEWORK

Many studies have worked on the climbing strategies among climbers. The impact of the visual strategies on performance has been particularly studied [2] with a focus either on the climbing path identification before the ascent [3].

These approaches have significantly contributed to the understanding of the performance and improved the design of training programs. However, a few studies have specifically dealt with the performance *in situ* and from the experiential background of the actor.

Some studies focused on the analysis of the athletes' experience course and led to the discovery of strategies that coaches and athletes didn't know of. They suggested new training methods in table tennis [4], freestyle skiing[5], sailing [6] or trampoline [7].

In order to formalize the exploration methods and natural boulder climbing methods and to make useful training modeling methods, this study focused on the description of PR mobilized by expert climbers during the climbing of a natural boulder. This study was inspired by the conceptual framework of culturalist anthropology [1]. The purpose of this study is specifically on the deployment of climbers' PR through the rules and meanings which are mobilized by the climbers during different moments of the performance achievement.

METHODS

The PR types have been modelized starting from the specific study of the sequence of the rules, which are used by the climbers to indicate their climbing experience. These types have enabled to finely characterize some ordinary meanings grouped around the concept of the climbing "method", within the community of the climbers' practice.

Participants and context

Four climbers from regional to national level volunteered to participate in this study.

The climbers' activity was studied on the work on natural boulder they did not know.

Data collection

Parts 1. Audio-video data. A recording of the climbers during their climb was realized with a digital camera. The trials were all filmed and viewed both by the climber and the researcher to identify the most significant ones for the climber. The video samples were the support of a self-confrontation interview (SC).

Part 2. Verbalization data were collected during SC made with the climbers immediately after the video was edited. Each climber was invited to comment on the images of his performance and to state (a) the rules he followed during the action (R), (b) his perceptions and sensations (S), (c) the circumstances in which his actions and perceptions were part of (C), (d)the expectations and knowledge he used(A) and (e) the judgments on his action (J).

Data processing

The SC data were retranscribed verbatim in Part 2 and synchronized with the data from Part 1.

The data splitting was done from the identification of the meanings of the objects which are attributed by the actor to the actions and the events viewed while the SC. The analysis of all the PR enabled the characterization of "type methods" specific to each climber during his ascent.

RESULTS AND DISCUSSION

Quantitatively JM realized 22 trials, failed to climb the boulder and stated 29 rules.TC realized 18 trials, succeeded in climbing the stand up version of the boulder and stated49 rules. GS realized 25 trials, failed to climb the boulder and stated18 rules. TB realized19 trials, succeeded in climbing the variant of the boulder and stated 21 rules. Among all the rules, five were commonly shared by all climbers. They fed some similar PR, especially at the beginning of the boulder exploration.

Four exploration and boulder ascension "types methods "were made-up and typical PR were discussed. The data also revealed some similar (A) and (J) during the first trials, especially at the beginning. These PR components of the climbers spawned an identical tracking of rules at the beginning of the exploration of the boulder. These trials were unsuccessful. Three of the four climbers changed the PR and two of them succeeded in at least one (TC) or two (TB) of the proposed routes. All the climbers used PR to simplify the difficulty of the "crux". Specific knowledge of each climber can be adapted tot he climbing contexts and to each climber in training.

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Importance of attention in mental training, analyzed through falling

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***Summary* — Attention is an important factor in mental training. Fear of falling distracts attention from climbing. The effect of fear of falling was studied with thousands of intermediate to advanced climbers. Improvement in use of attention was collected based on students' comments and instructor observations, which hypothesized that attention in the moment was enhanced during falls, fear was diminished, and attention was available to focus on climbing.**

INTRODUCTION

I collected a lot of subjective information and am sharing a hypothesis for the importance of attention in mental training. I've taught thousands of climbers and witnessed the importance of attention to reduce fear. A vertical wall (not overhanging) was used to create tangible wall impact fears. The approach to fall practice was one of increasing stress in small increments and having students pay attention to how they practiced. They focused their attention on somatic activities of breathing, eye focus, and proper body positioning. Doing this helped them learn the skill of falling, diminish fear of falling, and allow attention to be available for climbing.

METHODS

"How" we practice falling determines the neural networks in the brain. How we breathe, where we look, how we transition into the fall, our body positioning, and where our attention is all bring quality to the formation of such neural networks. Thus, we set up the falling drills in increments: short top rope falls, longer top rope falls, and finally lead falls. Incrementing this way minimizes attention distractions and helps students focus on the task of falling.

Our approach included three tenets:

1. We need to have our attention focused on climbing to be effective. Fear of falling distracts attention from climbing. Therefore, diminishing fear of falling makes attention available for climbing.
2. Diminishing fear of falling requires learning how to fall correctly. We identify elements in the body to focus attention on: breathing, eye focus, and proper body positioning.
3. The learning process converts stress to comfort. By approaching learning as a conversion of stress to comfort we're aware that only small increments of stress can be converted. Incrementing from short top rope, to longer top rope, to lead fall drills helps assure stress is being converted into comfort effectively.

Setup: We use a lead rope, clipped into several quickdraws (5 or 6). The climbing terrain was moderate so the difficulty doesn't tire students from doing repeated falls. Student begin by climbing to a point about 3 meters below the highest clipped bolt, thus beginning on top rope. They do 3 increments of falling practice with discussion debriefs between: short top rope, longer top rope, and lead.

Students are instructed to focus their attention on exhaling during the fall (breathing), looking down into the fall zone (eyes), and assuming proper body positioning — arms/legs shoulder-width apart and bent — (body). These breathing/eyes/body (BEB) elements are refined as students progress through the three falling drills. They stayed at each increment until they were comfortable. Doing this insured they focused their attention on learning how to fall correctly, and diminish fear.

RESULTS

Case study: New River Mountain Guides - 2015 [1]

Elaina Arenz of New River Mountain Guides taught a trad camp at the New River Gorge, which included learning to fall on self-placed gear. She had one student who was very resistant to the falling exercises. Initially, the student was timid. Elaina started her with toprope falls of about one meter. Elaina instructed her to exhale throughout the fall, look down, and assume proper falling posture. Eventually, she took some one meter toprope falls; she became visibly more comfortable. On day two, Elaina ran her through falling drills again. She was more willing to engage, showing progress more quickly. She progressed to the point of taking longer toprope falls of about three meters, but couldn't progress to lead falls.

Comments from students: [2]

"I was crippled by my fear of falling. Now I feel I have the tools to approach it with a different mindset and succeed at my potential."—Nellie (Vertical World)

"The clinic really helped me conquer some of my fear of falling, but most of all, it helped me commit and stay focused on the task at hand."—Sara (Horizon Roc, Montreal)

DISCUSSION

Students' experiences, comments and instructor observations pointed toward the importance of attention in mental training. Results indicated student became more comfortable with falling, diminished fear of falling, and improved their ability to focus attention on climbing.

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Hang Board Performance Time Across Multiple Hangs in Normoxia and Normobaric Hypoxia

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Summary **– Lower grade to intermediate level[2] rock climbing participants (n = 13) performed a straight arm hang to failure on a hang board using sloped hand holds in normobaric hypoxia (NH) and normoxia (NM) in a repeated measures (separated by one week) and counter-balanced study design. Notably, climbers performed the hang to failure x 10 with a 2-min rest in a hypoxic chamber and believed they were in NH both times – this was necessary to increase reliability across conditions. Performance variables included: hang time to failure, immediate pre- and post-hang heart rate (preHR, pstHR), rating of perceived exertion (RPE), immediate pre- and post-hang peripheral oxygen saturation (preSpO$_2$, pstSpO$_2$) across the 10 trials. We hypothesized NH would result in a lower SpO$_2$ and a decrement in HT. Furthermore we hypothesized preHR, pstHR, and RPE would be higher for each hang repetition in NH. Expectantly, pre and pstSpO$_2$ were significantly different between conditions, confirming low oxygen in NH. No other variables were significantly different. NH seemed to have no effect on average hang time performance using a straight arm hang on sloped hand holds.**

INTRODUCTION

Acute altitude exposure has the potential to decrement climbing performance because of low oxygen saturation (SpO$_2$) with inflated resting and exercise heart rate (HR) responses and rating of perceived exertion (RPE), thereby leading to a possible diminished hang time (HT) due to metabolic alternations[3], among other consequences. Oxygen transport to working muscle is compromised with a greater reliance on anaerobic pathways leading to quicker fatigue during acute altitude exposure, especially during aerobic activities[5]. Recovery from fatigue may also be extended in hypoxia[5]. Most of all, altitude is known to affect all functional systems of the body, including skeletal muscle, central nervous system, and cardiopulmonary[3]. Many recreational climbers live and train at sea level and travel to altitude during climbing vacations, thus, we sought to explain acute changes in the aforementioned, select physiological variables during repeated, straight arm hangs to better understand the extent of potential performance decrements.

METHODS

Two lower grade and 11 intermediate rock climbers (n = 13, females = 4; IRCRA Reporting Scale[2] 9-16) in a repeated measures, counter balanced format performed 10 straight arm hangs on sloped hand holds with 2-min rest in normobaric hypoxia (NH, at 14.5% inspired oxygen; 3,200 m ASL) and normoxia (NM) conditions, separated by one week. In both conditions, participants believed they were in NH in order to increase reliability. A habituation session was held prior to data collection to familiarize climbers with the hypoxic chamber (Hypoxico Inc., New York, NY) environment, instrumentation used, and hang board sloped holds (Metolius Simulator 3-D, Fig 1). Chalk was allowed at will. HR was observed via a chest strap transmitter (Polar Electro Inc., Lake Success, NY) and SpO$_2$ recorded via a finger-tip pulse oximeter (General Electric Ohmeda TuffSat, Finland) throughout all hangs and recorded immediately pre- and post-hang. RPE was asked immediately post-hang using the Borg[1] categorical ratio scale (0 = no exertion, 10 = max exertion). The same timer recorded total hang time, determined as the time between when the feet left and returned to a ground mat. Statistical analysis included paired t-tests with significance set at $p < 0.05$.

RESULTS

All data reported as mean ± SD. Ape index, height, weight, age, number of years climbing, and climbing frequency are reported in Table 1. No differences ($p > 0.05$) with respect to average hang time, preHR, and pstHR between NH and NM, respectively, were observed (24.7 ± 5.4 vs. 23.3 ± 5.6 sec; 91.3 ± 2.3 vs. 92.0 ± 1.6 bpm; 120.9 ± 3.8 vs. 127.7 ± 2.2 bpm). No difference in RPE was observed between NH and NM, respectively (4.9 ± 1.2. and 5.2 ± 1.1). Pre and pstSpO$_2$ values were significantly different ($p = 0.00$) between NH and NM, respectively (90.7 ± 1.2 vs. 97.1 ± 0.3 % and 90.5 ± 0.7 vs. 96.9 ± 0.4 %). Lastly, Figure 1 depicts hand position and Figure 2 showcases hang time to failure across all trials and between conditions.

Table 1. Participant Characteristics.

	Ape Index (cm)	HT (cm)	WT (kg)	Age (yrs)	Climb Experience (yrs)	Climb Frequency (days·wk^{-1})
Mean±SD	175.6±7.6	173.1±5.6	68.3±7.8	26.2±8.7	5.5±6.6	3.0±1.3

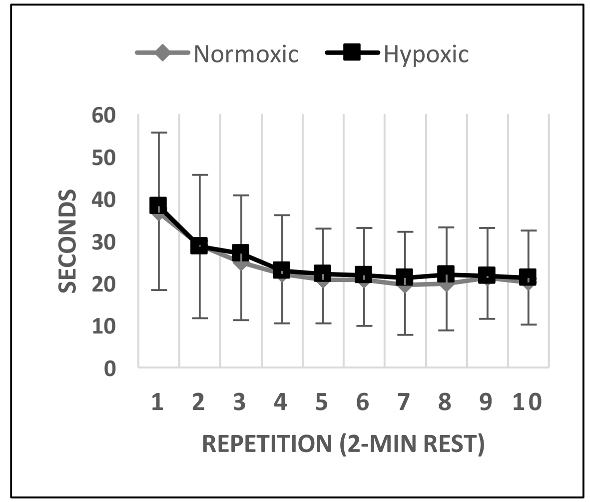

Figure 2. Mean ± SD. Hang time (sec) across trials for N and NH.

Figure 1. Hand position for hangs.

DISCUSSION

The primary purpose of this investigation was to explain potential physiological differences between NH and NM during repeated, straight arm hangs. A significant difference in pre and pstSpO$_2$ between conditions confirmed a hypoxic environment[5]. Because no difference in hang time, preHR, pstHR, and RPE was determined between conditions, it seems NH had little effect on performance in this setting under repeated hangs from the hands. Thus, part of our hypothesis was not supported. Hence, the 2-minute recovery was adequate during NH and allowed for overall slightly greater hang times across trials vs. NM with no change in HR or RPE. Interestingly, a similar pattern of hang trial fatigue to our observations (Fig 2) was formerly established in NM by Watts et al[4]. Ultimately, if a climber is considering acute or intermittent NH training prior to an altitude climbing excursion, they should not expect much of a training effect, especially if monitoring HR, which was actually lower post-hang in NH.

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Comparing Climbing Kinematics of Children with and without Pathological Gait

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***Summary* – Climbing is a sport requiring strength, flexibility, and coordination. Because children with cerebral palsy have deficits in each of those areas, climbing was proposed and evaluated as a recreational therapy. Participants completed a uniform set of lateral and vertical steps (8 to 16 in). Limb force generation, force assistance provided, joint excursion angles, and modeled muscle fiber lengths were examined. Results were compared with those of a typically developed control population. The CP population required more force assistance and had reduced ranges of motion, yet achieved similar/greater fiber lengths for ankle plantarflexor and knee flexor muscles.**

INTRODUCTION

Climbing is a physical activity requiring and developing strength, flexibility, and coordination in typically developed (TD) children and adults [1]. Children with cerebral palsy (CP) have lower strength capabilities, poor flexibility, hypersensitive stretch reflex (spastic) responses, and reduced coordination/neuromuscular control [2]. Climbing may be an ideal environment to address the variety of movement issues for the CP population.

PURPOSE

We can study the CP and TD populations to establish whether or not climbers with CP can utilize body weight support and range of motion (ROM) comparable to TD climbers, with the goal of improving muscle strength, joint flexibility, and coordination. In turn, this evidence may support climbing as a therapeutic activity.

METHODS

Three subjects with diplegic CP and the ability to independently ambulate (two with assistive devices) and five subjects for the TD population were recruited, all between the ages of 5-18. An 18-foot tall climbing wall was instrumented (Fig. 1a) with six vertical force plates (Bertec Corp., Columbus, OH) and a 10-camera motion capture system (Vicon Motion Systems Ltd., Oxford, UK). Trials were collected from a uniform starting position to different climbing grip destinations (most difficult = 16” lateral, 16” lateral, Fig. 1b). MSC.Adams and the LifeMod plugin were used to obtain joint excursion angles [3]. In OpenSim, joint angles were applied to the Gait2392_Simbody model to yield lower limb muscle-tendon lengths, which were analyzed to estimate muscle stretch [4].

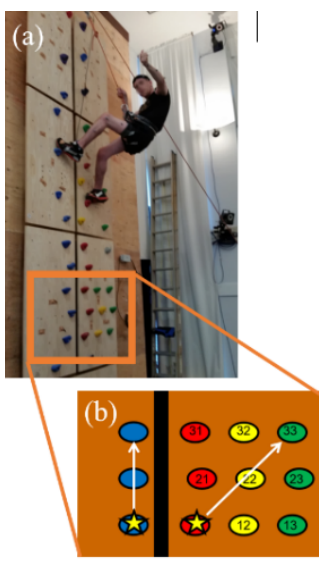
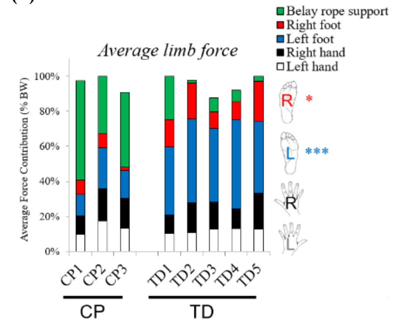


Figure 1 a) A climber on the instrumented wall. b) Foot transition from starting point (starred) to destination

RESULTS

Outside assistance to support body weight on the climbing wall is nearly four times greater for the CP population (Fig. 2, 43.9% vs. 8.4%, $p<0.01$). Lower limb force production is significantly reduced (Fig. 2, $p<0.01$ and $p<0.001$), while there was no statistical difference observed between populations for the upper limb force production. Joint excursion angle ranges were decreased compared to those of the TD population, yet OpenSim modeling reveals similar mean stretch for the ankle plantarflexors and knee flexors (Fig. 3).

(2)



(3)

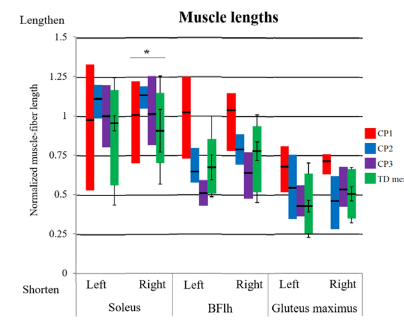


Figure 2 Limb force and belay rope assistance measurements for all subjects.
Figure 3 Muscle fiber length for all subjects, normalized by optimal fiber length.
*$p<0.05$, **$p<0.01$, ***$p<0.001$

DISCUSSION

Climbing is a unique recreational activity in that it is already equipped to address biomechanical deficits with built-in belay rope support and conscious movement planning. Subjects with CP were able to climb even with significantly reduced lower limb force production. Additionally, muscle stretch was achieved even with inherent coordination and flexibility issues. Using climb training as a tool for strengthening and stretching may benefit children with CP as it does TD children, and it has the advantage of being fun for participants; this study elicited 100% compliance along with requests for additional climbing sessions. Future studies should investigate direct impact of climbing on functional measurements like dynamometer strength tests and passive stretch ROM. Ongoing studies in this laboratory are examining potential changes in body weight support and limb force production, ROM, and muscle stretch as a result of habitual climbing.

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Motivation and Habit Formation: An Exploration of Rock Climbing and Its Implications for Exercise Participation

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***Summary* –The motivation and habits of rock climbers were investigated using mixed methodology in order to better understand exercise participation. Forty-one patrons of a southeastern United States climbing gym completed a demographics form and adapted Sports Motivation Scale II (SMS-II), while thirty-six participants completed the Rock Climbing Motivation Survey (RCMS). Those with higher climbing frequency reported significantly different levels of identified regulation than individuals who climbed less often (*p*= .006). According to a thematic analysis, exercise balance and personal growth and challenges were the most commonly reported themes of motivation for rock climbing; the most frequently cited barriers were injury and time. Participants reported external motivators to climb upon initiation of the sport, but relied on internal motivators to continue climbing. These findings, which are are supported by current literature on physical activity, may be applicable to promoting exercise participation and maintenance.**

INTRODUCTION

Internationally, only 23% of adults satisfy exercise guidelines proposed by the World Health Organization (WHO) [1]. Given the known health benefits and increasing availability of rock climbing, participation in rock climbing as a means of exercise should be strongly encouraged [2-4]. Personal factors, such as motivation and habituation, are crucial to establishing habits and maintaining physical activity [5, 6]. The Model of Human Occupation (MOHO) and Self-Determination Theory (SDT) were used to explore the motivation of rock climbers. MOHO addresses the impact of motivation upon habituation [7], while Self-Determination Theory (SDT) delineates a motivation continuum applicable to exercise participation [8-12]. SDT categorizes motivation on a spectrum from most to least autonomous: intrinsic regulation, integrated regulation, identified regulation, introjected regulation, external regulation, and non-regulation [14].

PURPOSE

The study's purpose was to understand exercise participation by investigating the motivators for rock climbing and climbing habits. Two research questions were explored.

1. What motivates recreational rock climbers?
2. Are the motivators different among rock climbers according to their habits?

METHODS

After receiving IRB approval, forty-one patrons (19 men and 22 women) of an indoor rock climbing gym in the southeastern United States participated in an online Qualtrics survey. The survey consisted of a demographics form, an adapted version of the Sports Motivation Scale II (SMS-II), and the Rock Climbing Motivation Survey (RCMS). Each participant completed the adapted SMS-II; however, only 36 completed the RCMS. The SMS-II is a valid and reliable, 18 item Likert-type measure addressing motivation to participate in a particular sport according to SDT [13]. Founded on exercise adherence literature, the RCMS, which was created for the study, uses six open-ended questions to prompt responses regarding motivation to rock climb. Cronbach's Alpha and the Mann-Whitney U compared quantitative data from the SMS-II, while a thematic analysis using NVivo 10 software evaluated qualitative information from the RCMS.

RESULTS

Internal consistencies for the six subtests of the SMS-II were determined using Cronbach's Alpha and were: intrinsic regulation (α =.852), integrated regulation (α =.859), identified regulation (α =.818), introjected regulation (α =.640), external regulation (α =.509), and non-regulation (α =.398). All sub-tests with coefficient greater than .800 were included in data analysis. Climbing habits were measured by frequency of climbing. The Mann-Whitney U compared climbing frequency to motivation; a statistically significant difference was found when comparing identified regulation and climbing frequency (p=.006). No significant differences were found when comparing intrinsic regulation (p=.073) and integrated regulation (p=.712) with frequency.

Responses from the RCMS were categorized into several themes addressing climbing motivation and barriers. Figure 1 displays a hierarchy of coding for motivation themes. Personal growth and challenges and exercise balance were the most reported sub-themes of motivation. External factors related to climbing were most frequently reported for initiating the sport, while internal factors were most cited as reasons to currently climb. Figure 2 demonstrates the hierarchy for barriers to climbing; injury and limited time/other obligations were the most frequently reported barriers to climbing.

Figure 1: Motivation Sub-theme Hierarchy

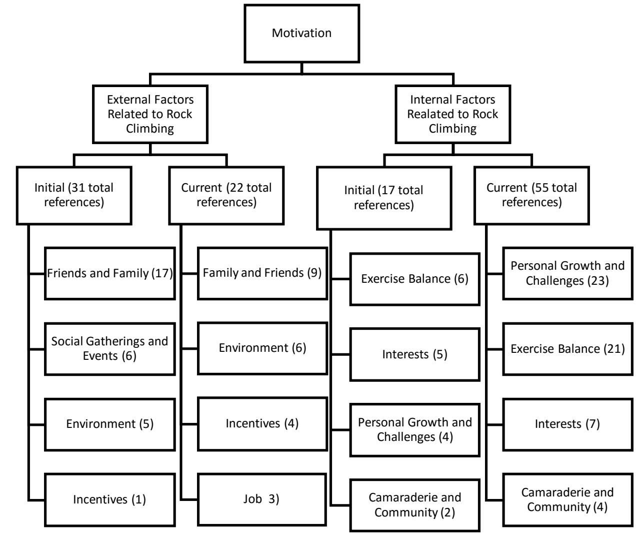
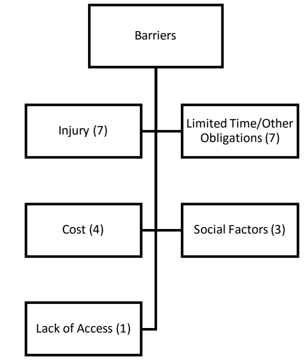


Figure 2: Barriers to Climbing



DISCUSSION

According to climbing frequency, participants reported significantly different levels of identified regulation, a relatively autonomous form of motivation based on internal values and goals [8, 14]. These findings are supported by evidence that relatively autonomous motivation and habituation are related [9-11,15]. Rock climbers were initially motivated by family and friends (external factors), but continued to climb in order to fulfill personal growth and challenges, and exercise balance (internal factors). Climbing barriers were reported as due to injury and time. These findings are supported by literature, which explains that lack of time and social support commonly prevent exercise and sport participants from engaging in physical activity [5, 10, 16]. Awareness of these personal factors supports better understanding of rock climbing participation and may promote compliance to the physical activity recommendations of the WHO. Applying this knowledge to physical activity participation may contribute to an overall increase in health and wellness outcomes.

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Case Study of a Climbing Activity as an Educational Tool for Primary School Children Throughout a Whole Academic Year

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Summary - **An innovative climbing activity was designed and put into practice throughout an academic year in a public school located near a well known climbing area in Spain. Participants were primary school children from 6 to 12 years old. Different qualitative/quantitative research tools were used to study the evolution and effectiveness of the project, mainly concerning the children's acquisition of new skills and capabilities. Results are showing how climbing can be an excellent educational tool and can contribute in a community connecting children and their families with the cultural and natural environment.**

INTRODUCTION

Rock climbing appears to provide a valid and beneficial activity for various educational purposes and contexts [1]. There are many studies concerning the benefits of including rock climbing experiences in schools both as an indoor activity, or as part of Adventure Education Programs [2, 3]. While most of these studies included the climbing activities as part of a Physical Education programme [4], the current project aimed to encourage and develop new skills for children within a long-term activity project that contributed to the development of new habits in regard to the relationship with oneself, social and natural environments. The purpose of this study was to understand the creation, dynamics and educational capabilities of an innovative climbing activity that was set for the first time in a concrete learning and cultural context.

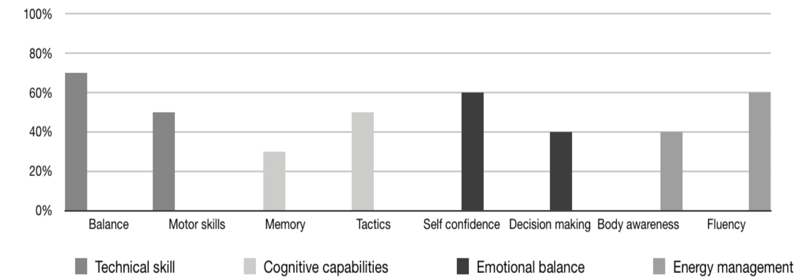
METHODS

A specific methodology was designed to analyse the complex scenario to be studied. Qualitative case study research methods were tested and put together in order to get a clear and multifaceted overview of the reality being tested and different variables were observed to outline the context, participants and the activity itself. Research tools included researchers diary, session diary, activity notebook made by the students, in depth and group interviews, video recordings, photographs and diverse evaluation systems. Data was gathered from October 2013 to June 2014 with children between 6-12 years old, during indoor climbing sessions that basically consisted in a wide range of games adapted for the climbing activity and facilities. The program had enough flexibility to adapt to the changing conditions, including improvements in the climbing indoor area or the rising amount of students and their families regularly being involved in the project.

RESULTS

Gathered information was analysed through the qualitative data analysis software ATLAS.ti. Results from the evaluation forms, researcher's observation and feedback given by the participants highlight a

number of key findings. Findings concerning children's acquisition of abilities and the introduction of the new activity in the school context were: there were visible improvements in technical skills, cognitive capabilities, emotional balance and energy management skills. Gained attitudes related to responsibility and initiative skills The project is a long-term intervention with a solid and coherent learning program that has led to different outdoor experiences related with the rich natural setting where



it is based.

Figure 1 Improvement of specific capabilities acquired in the four main areas of interest expressed in percentage. Data comparison between observation at the beginning and after 6 months of practice.

DISCUSSION

The study showed the creation, evolution and outcomes of this innovative climbing program which gives special importance to learning through games and direct experience. The findings provide a reference point for those undertaking similar projects in other social and cultural contexts [5]. This study provides an in-depth theoretical content about the definition of climbing from different perspectives, a comprehensive review of the literature around climbing didactics, innovative approach on methodology and guidelines to contribute positively in a community through an activity that connects children and their families with the cultural and natural environment where they belong [6].

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Climbers for Bat Conservation: Engaging Rock Climbers Through Citizen Science

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Summary - The amount of data documenting crack and crevice (herein simply "crevice") use by bats is increasing [1, 2], and, although these resources are valuable, they are inconspicuous on the landscape [3]. It is likely that many more crevice roosts exist, but are rarely encountered by biologists. Obtaining a better understanding of bat use of crevices would provide biologists and land managers with invaluable information for conserving bat populations. The rock climbing community represents a specialized group of recreationist with unparalleled access to these areas and could therefore serve a critical role in bat conservation.

INTRODUCTION

In recent years, North American bat populations have been presented with new conservation threats. With the increase in wind energy development has come the understanding that turbine collisions have claimed an estimated 600,000 bats annually [4]. Even more problematic is the emergence of White Nose Syndrome in North America. Starting in 2006, bats began dying due to infection of a cold-adapted fungus and it is estimated that millions of bats are dying annually [5]. Because it is likely that bat populations are declining there is a need to quantify bat population parameters, such as survival, abundance, and persistence. Estimating population dynamics requires knowing where populations are, and for many species, biologists are still identifying important roosts that can be monitored. This is especially true for crevice-roosting bats. However, the rock climbing community visits features where crevices are abundant, and there is existing data that climbers encounter bats (climbing accounts at mountainproject.com). Developing and maintaining a constructive relationship between user groups and bat conservation community can be challenging. Many of the challenges arise when access to recreational resources are jeopardized by conservation measures [6]. The collaborators wanted to develop a mutually-beneficial relationship with the user group (climbers) that allowed them free input on: if a relationship should be developed, how that relationship might look, and how the relationship can benefit both groups.

PURPOSE

The purpose of this project were to: (1) acquire more information about where crevice roosts are to understand bat roosting ecology; (2) locate roosting colonies with substantial bat populations as potential population-monitoring locations; and (3) develop a mutually-beneficial collaboration with the climbing community that could be used to expand knowledge of bat roosting ecology.

METHODS

We invited bat biologists, leading climbers, and land managers from northern Colorado for a World Café meeting [7]. The World Café methodology is a process of engaging participants in multiple open questions and facilitates cross-pollination of ideas by interchanging members among multiple small groups. Participants discussed the challenges and opportunities that a collaboration would present. Individuals aired concerns and brainstormed ideas for developing and expanding the collaboration. Throughout the discussions, important comments and points were captured artistically (by Karina Mullen Branson of ConverSketch) so that participants could see the development of common issues and future participants could see how the process developed and how the discussion evolved.

RESULTS

During the World Café meeting, biologists, land managers, and climbers were supportive of developing a collaboration to collect information on bats. The biggest challenges would be overcoming the external belief that the data would be used to restrict access to climbs. Thus, the groups felt the biggest priority was to refine the goals for the project and gain trust within the climbing community by giving public presentations and bat-survey outings. We also developed an iNaturalist project page and mail-in postcards for climbers to submit data for the project. Most data reports have come via postcards, but some have come from direct solicitation from The Mountain Project (mountainproject.com). Most accounts are of single-roosting bats, but one account has over 100 bats, which is a potential future study site.

DISCUSSION

Development of the collaboration was met with less resistance than expected; however, there is some concern within the climbing community that the data will be used to preclude climbers from climbs. Seasonal climbing closures exist for raptors and bats in Colorado, but most climbers have been supportive (Will Keeley, City of Boulder Open Space, personal communication).

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Nutrition and Hydration Strategies to Enhance Sport and Multi-pitch Climbing Performance

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INTRODUCTION

The relationship between rock climbing performance and nutrition appears to be a long standing affair with a common mantra of "eat to make you light". As registered dietitians who climb for pleasure we have all noticed interesting food and fluid consumption behaviors at the gym and the crag. Being in the profession of studying food and food-related behaviors, we must question why a climber might choose to avoid drinking water or eating carbohydrates before repeated ascents up a tall wall with tiny holds that require physical and cognitive tenacity.

We understand that the unique physical act of climbing rock and ice requires an exceptional anthropometrical profile to be competitive. We are also keenly aware that *accurate* nutrition education is minimally reinforced among many who competitively or recreationally climb. It is likely that numerous climbers attain or maintain a lean physique and low body weight through nutritionally unsound methods that consequently limit training capacity and may jeopardize overall health.

Despite the paucity of literature pertaining to the nutrition and hydration needs of climbers, this paper summarizes our attempt to interpolate, from other-activity-based research, suitable food and fluid intake strategies for sport and expedition climbers. Within the context of sport climbing, we will discuss nutrition-related factors associated with the onset of fatigue as well as nutrition strategies for optimal recovery between daily training sessions; we will also address the unique fueling requirements for those who undertake extended traditional multi-pitch climbs.

IN-SITU NUTRITION AND HYDRATION STRATEGIES TO OPTIMZE TRAINING

To understand the potential nutritional needs of climbers a brief review of climbing physiology is necessary. High-performance climbing requires an exceptional overall strength to body weight ratio and especially in regards to the small and large muscle groups of the upper body (1). Because of this, most elite climbers are extremely lean. Previous research conducted on World Cup climbing competitors found average body fat levels for women of 10% and 7% for men (1). Climbers also tend to be somewhat smaller in stature in regards to height and weight; the average weight of elite female and male climbers has been reported to be <55 kg and <70 kg, respectively (1). This is of importance because when considering nutritional strategies that are likely to be practiced on a regular basis, we must also consider long-term body weight and composition goals. In general, climbers do not want to gain weight but still must meet nutrition and hydration needs to support and recover from training and competition demands.

As there is evidence to indicate that a steady state is not reached during the climbing of a particular route, there is likely high utilization of anaerobic pathways (2). As such, utilization of local muscle glycogen is the primary fuel source used to produce the ATP necessary to complete a series of successive ascending moves. Additionally, it is estimated that the rate of energy expenditure associated with active climbing is approximately 10-11 kcal/min, regardless of climb angle or difficulty (3); thus for any given single-pitch or competition route, energy expenditure is relatively low. This said, no research to date has measured total energy expenditure for an entire training session at the gym or crag. It is not uncommon for long training sessions to last several hours and include active time on belay and an arduous hike to and from various crags while carrying gear. Therefore, it is possible that a "typical" four-hour climbing session could utilize upwards of 1200 kcal (similar to running a ½ marathon) but a short session at the indoor climbing wall may only utilize ~ 200 kcal.

Meeting climbing-associated nutritional requirements for optimal training, recovery and competition is a *long-term process* and nutritional issues that may be of consequence in high-level sport and competition climbing are those practices related to daily nutrition and hydration. This includes appropriate in-situ nutrition and hydration strategies. Assuming the above points regarding the physiological demands of climbing are accurate, it is possible to develop nutrition and hydration strategies likely to benefit in-situ training and competition performances. Using evidence from nutrition interventions used during intermittent exercise, as well as data from climbing-specific studies, we propose the following six key points:

1. Optimal climbing performance requires that, long-term, any in-situ nutrient recommendations will not lead to weight gain or increases in body fat stores. It is likely that current research regarding optimal carbohydrate intake recommendations for most athletes presents us with unrealistic recommendations for most of the climbing population (4).

2. Optimal climbing performance is dependent upon consuming familiar foods and fluids that minimize GI distress.

3. A priori avoidance of localized muscle glycogen depletion via properly timed carbohydrate consumption will facilitate efficient and prolonged use of anaerobic glycolysis. Localized glycogen depletion has been shown to reduce rate of ATP resynthesis which leads to reduced anaerobic power output (4). Recommendation: Depending on activity level and body size, consuming between 3 and 7 g/kg/bw of carbohydrate throughout the day preceding a long training session will likely be sufficient for optimal glycogen synthesis.

4. Optimal climbing performance during long training sessions or competitions are supported with adequate fluid intake. Fluid intake is necessary for the transport of nutrients and oxygen to the working cells as well as removal of waste products. Dehydration of more than 3% of body weight is also associated with decreased mood, cognition speed, and feelings of greater perceived exertion (5-7). Recommendation: Depending on environmental conditions, most climbers could benefit from consuming ~ 250 mL water and ~ 250 mL sports drink each hour of training lasting beyond one hour.

5. Consuming easily digested carbohydrate-containing foods and beverages during long climbing sessions will likely attenuate feelings of fatigue and reduce perceived exertion, especially in the latter part of a session. Additionally, consumption of carbohydrates also prevents low blood glucose levels, which have been shown to impair cognition and reduce mood (8). Cognition is especially important in a sport where mistakes can end in tragedy. Even ingesting very small amounts (mouth rinse) of carbohydrate during intermittent activity has been shown to improve mood, cognitive performance, anaerobic power output, and decrease rating of perceived exertion compared to placebo; caffeine enhances this potentially centrally-mediated ergogenic effect (4, 9). Recommendation: Consuming 20-30 grams of carbohydrate each hour of training over one hour will likely delay the onset of non-acute physical and psychological fatigue. This amount can easily be consumed in liquid form and represents approximately 250 ml of sports drink each hour. If desired, 50-100 grams of co-consumed caffeine may provide additional benefit but amounts in excess of 200 g/day may lead to GI distress, tremor, anxiety, and/or sleep disturbances.

6. Consuming a source of protein prior to and during prolonged intermittent exercise may delay the onset of fatigue via maintaining plasma levels of branch chain amino acids. Evidence suggests a decreased rating of perceived exertion and perceptions of overall fatigue associated with higher circulating levels of branch chain amino acids; these ergogenic effects are thought to be centrally-mediated via inhibition of CNS-mediated, tryptophan-induced serotonin transmission (10). Recommendation: Consume 10 grams of complete protein no longer than two hours prior to training and an additional 10 grams every two hours of training. This amount can easily be consumed in liquid or food form and represents a very modest energy intake of 40 kcals per 10 grams of protein.

We can also assume that regularly neglecting to properly fuel and hydrate during training sessions, either as a result of failure to plan or as an inappropriate means for weight-control, makes for less than optimal training. This speculation is based on evidence from other activities but is currently the only way we have to describe the likely consequences of low nutrient and fluid intake during long training sessions. We certainly need more research that examines the potential ergogenic effects of fluid, carbohydrate, caffeine, and amino acid supplementation during long training sessions. Another area of future research is the examination of omega-3 fatty acids as a means to attenuate the inflammatory process.

NUTRITION OPTIMIZATION TO ENHANCE RECOVERY BETWEEN CLIMBING SESSIONS

Efficient recovery is critical to any athlete attempting to train multiple sessions within a 24 hour period. Proper nutrition may enhance the down time between sessions and/or climbs and contribute to positive subsequent training outcomes. Based on evidence supporting effective recovery (i.e. repair damaged tissue, enhance muscle glycogen and protein synthesis, reduce inflammation, enhance psyche) from similar activities, we recommend the following practical recovery nutrition strategies for rock climbers:

<u>Fluid</u> – Best practices would account for the individual's specific sweat rate to accommodate individual fluid recovery needs. Yet, by and large athletes may achieve euhydration (EU) before the next bout of training by consuming a fluid volume equivalent to 5 to 10 mL/kg BW (~2 to 4 mL/lb) in the 2-4 hours before the next session to achieve urine that is pale yellow in color while allowing for sufficient time for excess fluid to be voided (11). Water or a sports type beverage with ~6% carbohydrate solution may help to achieve EU. But if severe hypohydration (>5% body mass) is encountered, aggressive drinking of fluids with electrolytes should be encouraged to facilitate recovery for subsequent training or competition (12). In these instances, we recommend consuming 1-1.5 L of fluids for every kg lost until body weight is restored.

<u>Energy</u> – Assessing *individual* energy availability, which considers energy intake in relation to the energy cost of exercise, would be the best scenario for prescriptive energy needs for recovery from a climbing training session. An adult climber's caloric cost while climbing is ~10-11 kcal/min per kg of body weight regardless of the difficulty (2). General guidelines for adult athletes pursuing intermittent moderate to high intensity activities with more than 1 training sessions/day probably need ~30-45 kcals/kg of BW/day (13). However, minding the growth of young climbers and body weight goals of adults need to be considered. Avoiding Relative Energy Deficiency in Sport (RED-S), which is an inclusive description of many physiologic complications observed in male and female athletes who regularly under consume energy (14), is strongly advised.

<u>Carbohydrate</u> – An intake of ~1.0 to 1.2 g/kg/h, commencing during the early recovery phase and continuing for 4 to 6 hours, will optimize rates of resynthesis of muscle glycogen (15, 16), mainly due to the rate of glycogen resynthesis at ~5% per hour, early intake is crucial to maximize refueling time (17).

<u>Protein</u> – An early intake of high-quality protein sources (0.25 to 0.3 g/kg BW) post-exercise will provide adequate amino acids to build and repair muscle tissue and may enhance glycogen storage in situations where carbohydrate intake is suboptimal. Some evidence suggests ingesting protein during the recovery period leads to accelerated recovery from static force and dynamic power exercises and may lead to enhanced similar subsequent exercise performances (18,19). Ingesting protein (~ 20 to 30 g total protein, or approximately 10 g essential amino acids ensuring inclusion of leucine) during the recovery period leads to increased whole body and muscle protein synthesis as well as improved nitrogen balance (20).

<u>Fat</u> – Consuming dietary fat daily is necessary for optimal health, in particular essential fatty acids that are generally under-consumed by non-fish eating individuals. Some, but not all reports suggest that omega-3 (Ω3) supplementation helps to minimize muscle soreness and inflammation post-exercise (21, 22). More research needs to be conducted in order to form guidelines for specific ingestion times for Ω3s during recovery. With limited data, we suggest incorporating Ω3s into a daily food plan of ~1-2 g/d of an EPA:DHA ratio of 2:1 to help mitigate the effects of exercise-induced inflammation and DOMS (23).

<u>Micronutrients</u> –Deficiencies of specific micronutrients have long been associated with immune dysfunction while excess micronutrient intakes may impair immune function, an adequate dietary intake of iron, zinc, and vitamins A, E, B6 and B12 via food may help to maintain immune function and may assist with a more capable recovery from exercise (24).

<u>Nutrition-Related Ergogenic Aids</u> – It is beyond the focus of this paper to discuss nutrition-related ergogenic aids or dietary supplements. Thus, we refer you to these papers for a summary of the most recent evidence (25,26).

In summary, solutions to feeding challenges between training sessions require experimentation and habituation by the athlete, and should always be *individualized* based on personal needs and preferences. This is often an area in which the food knowledge, creativity, and practical experiences of a sports nutrition professional can make valuable contributions to an athlete's recovery and/or total nutrition plan.

LOGISTICAL NUTRITION ISSUES RELATED TO EXTENDED MULTI-PITCH CLIMBS

A multi-pitch climbing excursion can vary in length of pitches and completion time. An extended multi-pitch climb of greater than 6 pitches can pose serious logistical issues respect to meeting nutritional demands. Multiple factors shaping the climbers nutritional needs include but are not limited to the following: length of the climb, length of approach and descent, weather/temperature, weight of backpack and additional hauling packs, weight of the food, non-refrigerated food items, and limited cooking methods.

The weight of the backpack being carried on the wall can limit speed of climb and increase energy expenditure which in turn increases energy needs within the climber. Due to limited research in this area, a suitable approximation of the effect of performance on the climber carrying heavier backpacks can be seen with an Analytic Cycling Model proposed by Compton (27) which indicates that an additional one kg increase in weight (body weight or carried weight) can translate to ~2 second decrement in performance of a 100 meter uphill cycling time trial. Thus indicating that the heavier the carried pack, the longer the duration of the climb. An average multi-pitch climbing pack with all the gear (and no food) can weigh 22-44 kg, with a large gear rack alone contributing 5.5 kg.

As previously mentioned, climbers often seek a high power-to-weight ratio to accelerate climbing speed and reduce fatigue. Consequently, many seasoned climbers minimize the food and water taken to achieve lightness of the backpack. Leaving food and water behind can put the individual at risk for glycogen depletion, protein depletion, and hypohydration. Performance skills are negatively impacted with a 2% BW loss due to dehydration (11). Glycogen and protein depletion has been shown to reduce alertness and motor skill responsiveness along with contributing to fatigue of essential climbing-specific muscles and tendons, subsequently predisposing the climber to early fatigue and injury. Multi-pitch climbers could easily expend 1500-2000 kcals/day on exercise alone, over the course of a 5-7 hour climb (3). Climbing energy needs in combination with basal energy needs can put the multi-pitch climber's total daily energy needs close to 2700-3500 kcals while on the wall. Carrying this amount of energy in food can weigh over 4.5kg! Thus, the dilemma stands- adequate food or lightness and speed of a climb?

Additionally, typical foods consumed during a climb differ within individuals, and may at times meet the climber's energy needs, but may fail to meet nutrient needs due to relying on less-nutrient dense foods during the climb in lieu of minimizing carried weight and lack of refrigeration. A climbers recommended daily energy needs while attempting a multi-pitch climb should theoretically approach 7-12g/kg/day of carbohydrates, approximately 1.2-1.4g/kg protein per day, and around 20-30% total kcals coming from fat (17). Additionally, recommended intake while actively climbing ranges from 30-60 grams of carbohydrate per hour (28). A climber's ability to achieve these nutritional recommendations under the given multi-pitch conditions is likely rare, and future special attention needs to be given to achieving such nutritional goals. It is quite clear that further research and climbing-specific guidelines are in need for extended multi-pitch climbs.

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A Physiological Model for Rock Climbing: *The First 2000 Years*

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The objective of this historical review is to provide an overview of research relative to the physiological aspects of high level rock climbing performance published through the year 2000. Early researchers were challenged by the environment and movement nature of the activity and limitations in data acquisition technology. The *First 2000 Years* was an exciting period of exploration and discovery of ideas.

It is often said rock climbing emerged as the child of mountaineering. Movement on rock of smaller crags was performed as training for excursions to the greater peaks of the Alps and other mountain ranges. Climbers by nature tended toward a degree of competitiveness both internally with the self and externally with other climbers or the rock terrain. The expression of climber ability relative to a subjective rating of terrain difficulty naturally evolved.

The first difficulty rating system for rock climbing was developed in the late 1800's and was a precursor to the *Union Internationale des Associations d'Alpinisme* (UIAA) scale established in the 1940's. Other localized systems were developed in intervening years and the Yosemite Decimal System (YDS) for rating the difficulty of specific rock ascents appeared in the 1950's and became widely used in North America.

From a research perspective, performance in a physical activity requires some type of descriptor with a degree of objectivity. Description of the ability level of participants in research studies has typically been relative to one of the existing rock ascent rating systems according to the most difficult route the participant could currently ascend. Often adjectives such as "expert" and "elite" were also applied.

Since no common difficulty scale is used world-wide, and the existing scales are subjective, and perhaps in constant evolution, there has been a need for a standard for scientific research. Such a scale has been recently developed by Draper and others of the International Rock Climbing Research Association (IRCRA).[1] The IRCRA Ability Grouping Scale is open ended and currently extends from 1 (Level I ability) to 32 (Level 5 ability).

A look at how the "World's Best" performance has evolved from 1960 to 2000 is available in Figure 1. The 4th order polynomial trendline indicates a relatively steady increase in ability with a possible plateau tendency since 2010. The relationship of the plot with overall performance of climbers in general can be misleading since, in 2014, for example, only six ascents of IRCRA level 31 (5.15b YDS/9b French) were made. The relative distribution of climber abilities for a given year is not known. Nevertheless, the World's best Level 5 climbers appear to perform at higher grades through the period of years.

Early scientific research on rock climbing was focused on the general nature of the activity and the physical aspects of climbing along with various injuries suffered by climbers. In the latter 1980's, as competition rock climbing grew in popularity, research models traditionally used for the study of athletes were applied to climbing and climbers. The specific areas of performance physiology, biomechanics and sport psychology

have evidenced increased climbing research to date. A simple PubMed search with the terms "rock climbing" and "rock climbers", including clinical studies on injury and psychology topics, reveals the topical trends illustrated in Figure 2.

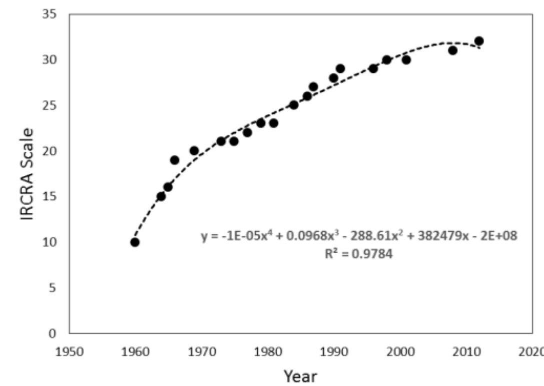

Figure 1. Plot of World's most difficult route ascent by year, 1960-2014.

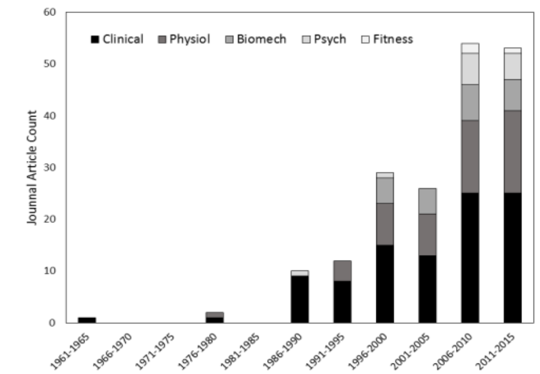

Figure 2. Published Research 1960-2015 via PubMed search on "Rock Climbing" and "Rock Climbers".

The PubMed search found 187 studies published through 2015. In comparison, a search on "soccer" revealed 7510 published studies. Of the 187 papers, only 54 were published through 2000. Most of these early published studies focused on development of a performance model for high-level rock climbing by integrating descriptive information of specific performer characteristics with the physiological demands encountered during difficult climbing.

Watts, et al.[2] published the first anthropometric study of competitive male and female sport rock climbers. Data were recorded at an international competition with 21 of 29 male and 18 of 21 female semifinalists participating. Seven of the 10 male finalists and all 6 female finalists participated. Climbers were found to be small in stature and low in body mass with low sum of skinfold measures. For finalists, body fat averaged 4.8±2.3% and 9.6±1.9% for male and female finalists respectively. Mermier, et al.[3] reported slightly higher values for percent body fat in male and female advanced climbers (5.11+ YDS, IRCRA ≈17).

The most obvious target for descriptive strength research with elite climbers was handgrip force. Several early studies found similar grip strength values in climbers ranging from 506 to 581 N for males[2,4,5,6] and 335±60 N for females[2]. Watts, et al.[2] found absolute handgrip scores to be rather "average" in elite climbers, however, when handgrip strength was expressed as strength:body mass ratio, males placed at the 80th percentile and females placed at the 90th percentile for age and gender matched North American population norms.

In the 1990's researchers began to question the specificity of handgrip dynamometry for measuring finger and hand strength in climbers. Simple observation of the hand-rock contact interface in climbing photographs revealed minimal use of finger-thumb opposition during ascents of the steep edging routes popular at the time. Grant, et al.[5] built a strain gauge apparatus to enable measurement of finger-curl force, without thumb opposition, in open and crimp positions. Peak finger-curl forces were 446.2±30.4 and

220±9.8 N for four fingers in open and crimp grip positions respectively for males and 320.7±17.6 N for open grip for females.

Limited early studies consistently found hand and upper body muscular endurance to be higher in accomplished climbers than recreational climbers or non-climbers.[4,5] Ferguson and Brown[7] found experienced climbers to have double the endurance time to 40% maximum handgrip during rhythmic maximum contractions than sedentary non-climbers. Furthermore, an enhanced forearm vasodilator capacity was found in the climbers.

A few studies prior to 2000 reported peak oxygen uptake (VO_2pk) values for rock climbers of 54.8 ±5.0 $ml \cdot kg^{-1} \cdot min^{-1}$ (treadmill running)[8], 55.2 ±3.6 $ml \cdot kg^{-1} \cdot min^{-1}$ (treadmill running)[9], and 52.0 ±4.7 $ml \cdot kg^{-1} \cdot min^{-1}$ (treadmill running)[10]. Billat, et al.[8] reported a VO_2pk of 22.3 ±2.6 $ml \cdot kg^{-1} \cdot min^{-1}$ for an arm pulling test and Booth, et al.[11] described a mean of 43.8±2.2 $ml \cdot kg^{-1} \cdot min^{-1}$ during fast climbing in seven highly skilled climbers.

Most of the research on the climber athlete of the *first 2000 years* associated various anthropometric and physiological measures with self-reported climbing ability levels of the research participants. Mermier, et al.[12] published the first attempt at associating climber characteristics with measured climbing performance. Forty four climbers attempted two artificial routes as on-sight top-roped climbing. Handhold contacts, or *moves*, on each route progressively increased in difficulty and maintenance of contact with successive handholds scored points. Together, the routes involved 63 *moves* up to 5.13 (YDS) or IRCRA 22. A principle components analysis reduced the large number of measured variables to three components: training, anthropometry and flexibility. Subsequent regression analysis found 39% of performance variance to be explained by the trainable factors, 15% by anthropometry and 10% by flexibility.

In addition to describing the characteristics of climbers, early research began to observe physiological responses and demands of the activity of difficult climbing. Billat, et al.[8] and Mermier, et al.[3] used Douglas bags to collect expired air during actual climbing for VO_2 analysis. Watts and Drobish[10] employed a non-motorized climbing treadmill (Brewer's Ledge Treadwall®) to record the first continuous VO_2 measurements during climbing at different angles. These studies found average climbing VO_2 to range between 24 and 32 $ml \cdot kg^{-1} \cdot min^{-1}$ regardless of terrain angle.

As portable expired air analysis systems became available in the 1990's, researchers began to observe physiological responses during actual climbing on indoor artificial walls and outdoors on real rock. Watts, et al.[13] found average and peak VO_2 of 24.7±4.3 and 31.9±5.3 $ml \cdot kg^{-1} \cdot min^{-1}$ respectively during ascents of a competition style indoor route. Booth, et al.[11] recorded a mean VO_2 of 32.8 $ml \cdot kg^{-1} \cdot min^{-1}$ during ascents of an outdoor route. In studies involving route ascents, VO_2 tended to plateau after 1.5-2.0 min of climbing which suggested a steady-state condition was attained. This steady-state condition was challenged by results that indicated significantly elevated post-climbing VO_2 [14] and elevated blood lactate concentration.[3,6,8,10,11,13] Post-climbing blood lactate means of 3.2-7.0 $mmol \cdot L^{-1}$ were observed in these studies. Slightly elevated blood lactate is not likely a concern as Watts, et al.[13] found pre-climb values of 3.5 ±1.9 $mmol \cdot L^{-1}$ in climbers who felt "warmed up and ready to climb" a competition style route.

Based on the integration schematic of Figure 3, Watts proposed an initial performance model for difficult climbing in a digital book publication in 2000[14] and subsequently published the first review on the physiology of climbing in 2004[15]. Based on the *First 2000 Years*, the proposed model components were:

- Small stature and high strength:mass ratio. This would be especially important for strength of the musculature that controls hand and finger positions.
- High level of isometric endurance, particularly for repeated contractions in the musculature that controls hand and finger positions.
- Moderately high aerobic power ($VO_2max \approx 50\text{-}55$ $ml \cdot kg^{-1} \cdot min^{-1}$ for males).
- High anaerobic power in the upper body …?

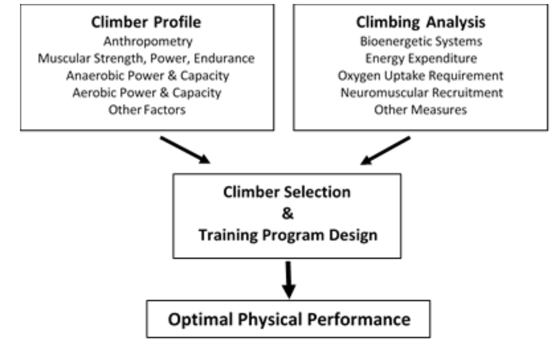

Figure 3. Integration schematic for developing a theoretical physiological model for rock climbing performance.

As Figure 2 indicates, the quantity of published research on climbers and climbing has increased tremendously since 2000. The next 2000 years will undoubtedly bring new answers … and new questions!

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Table I. Ability grouping for males and females and a range of reporting scales shown alongside the IRCRA scale.

Climbing Group		Vermin	Font	IRCRA Reporting Scale	YDS	French/sport	British Tech		Ewbank	BRZ	UIAA	Metric UIAA	Watts
				1	5.1	1		2	4	I sup	I	1.00	
				2	5.2	2			6	II	II	2.00	
				3	5.3	2+	3		8	II sup	III	3.00	
Lower Grade (Level 1) Male & Female				**4**	5.4	3-				III	III+	3.50	
				5	5.5	3			10	IV	IV	4.00	
				6	5.6	3+		4	12	V	IV+ V-	4.33 4.66	0.00
				7	5.7	4			14		V	5.00	0.25
				8	5.8	4+					V+	5.33	0.50
		VB	< 2	**9**	5.9	5	5a		16	V sup	VI-	5.66	0.75
				10	5.10a	5+			18	VI	VI	6.00	1.00
	Intermediate (Level 2) Female	V0-	3	**11**	5.10b	6a		5b	19		VI+	6.33	1.25
		V0	4	**12**	5.10c	6a+	5c				VII-	6.66	1.50
Intermediate (Level 2) Male		V0+	4+	**13**	5.10d	6b			20	VI sup	VII	7.00	1.75
		V1	5	**14**	5.11a	6b+			21	7a			2.00
			5+	**15**	5.11b	6c		6a		7b	VII+	7.33	2.25
		V2	6A 6A+	**16**	5.11c	6c+			22		VIII-	7.66	2.50
	Advanced (Level 3) Female	V3	6B	**17**	5.11d	7a			23	7c	VIII	8.00	2.75
		V4	6B+	**18**	5.12a	7a+	6b		24	8a	VIII+	8.33	3.00
		V5	6C 6C+	**19**	5.12b	7b			25	8b			3.25
Advanced (Level 3) Male		V6	7A	**20**	5.12c	7b+			26	8c	IX-	8.66	3.50
		V7	7A+	**21**	5.12d	7c		6c	27	9a	IX	9.00	3.75
			7B	**22**	5.13a	7c+			28	9b	IX+	9.33	4.00
	Elite (Level 4) Female	V8	7B+	**23**	5.13b	8a			29	9c	X-	9.66	4.25
		V9	7C	**24**	5.13c	8a+			30	10a			4.50
Elite (Level 4) Male		V10	7C+	**25**	5.13d	8b	7a		31	10b	X	10.00	4.75
		V11	8A	**26**	5.14a	8b+			32	10c	X+	10.33	5.00
		V12	8A+	**27**	5.14b	8c			33	11a	XI-	10.66	5.25
		V13	8B	**28**	5.14c	8c+			34	11b	XI	11.00	5.50
Higher Elite (Level 5) Male	Higher Elite (Level 5) Female			**29**	5.14d	9a		7b	35	11c			5.75
		V14	8B+	**30**	5.15a	9a+			36	12a	XI+	11.33	6.00
		V15	8C	**31**	5.15b	9b			37	12b	XII-	11.66	6.25
		V16	8C+	**32**	5.15c	9b+			38	12c	XII	12.00	6.50

Note: IRCRA stands for the International Rock Climbing Association; YDS for Yosemite Decimal System; BRZ for Brazilian scale, UIAA for the Union Internationale des Associations d'Alpinisme and Font for Fontainebleau. Sources: Watts, Martin, and Durtschi (1993), Benge and Raleigh (1995), Draper et al. (2011b), Schöffl et al. (2010), BMC (2007), Rockfax (n.d.), The American Alpine Club (2012).

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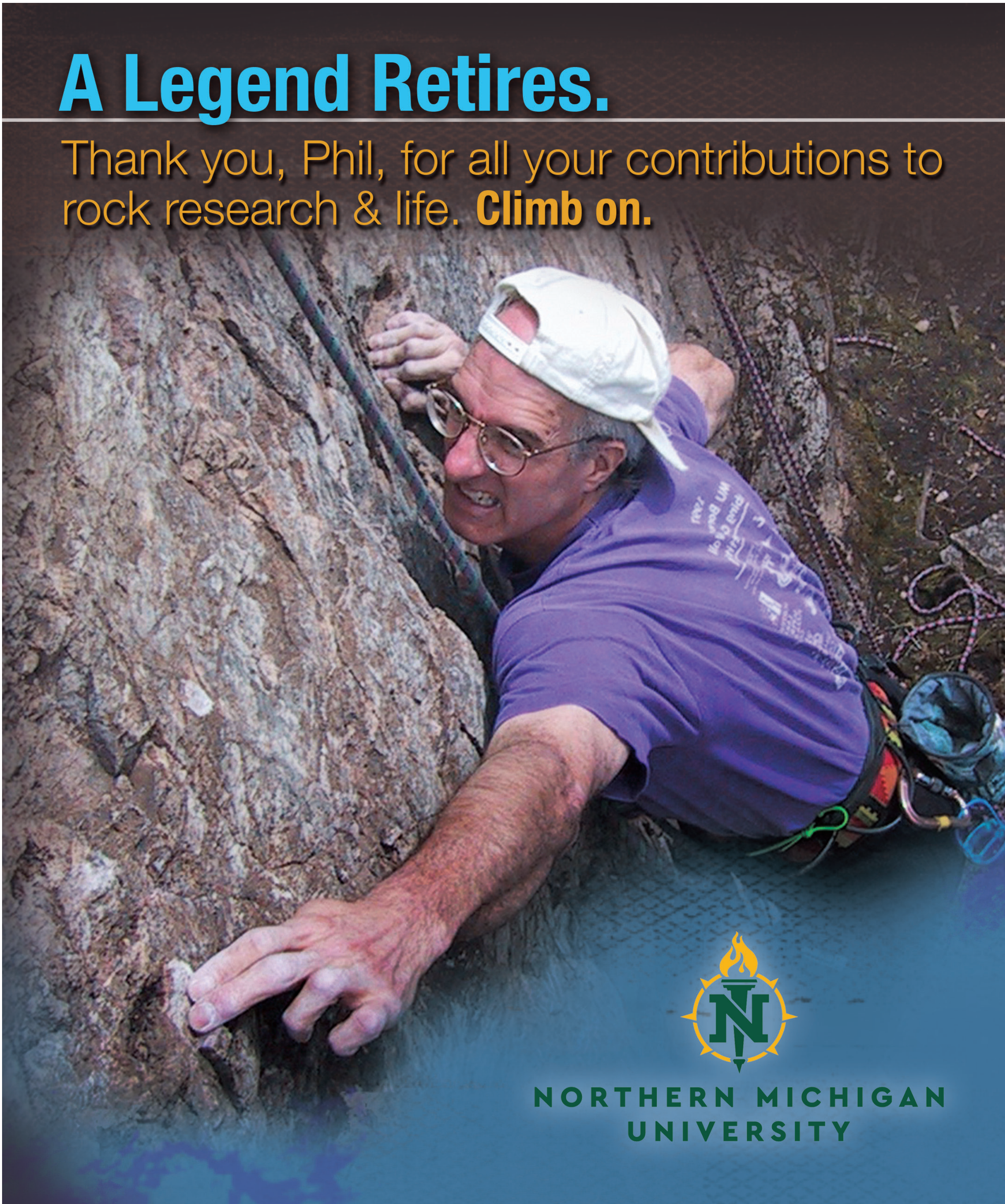
A Legend Retires.
Thank you, Phil, for all your contributions to rock research & life. Climb on.
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