ROCK CLIMBING TRAINING TECHNIQUES, RELIABILITY, AND RECOVERY IN WEIGHT-ASSISTED PULL-UPS

by

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ABSTRACT

Three studies were conducted on rock climbing. Study one investigated common rock climbing training techniques among competitive rock climbers via a questionnaire. Study two evaluated the reliability of open-handed and pinch grip weight-assisted pull-ups and whether chalk improved pull-up performance. Study three investigated two different recovery modalities, concerning closed-handed and open-handed weight-assisted pull-up performance, both of which are important abilities for rock climbers. The frequency of rock climbing training techniques (RCTT) as part of study one, was also investigated in competitive rock climbers (*n* = 174 usable). Chi square analyses revealed differences among age groups and three questions; differences also existed between gender and seven questions. Principal component analysis revealed five factors which explained 62% of the variance in questionnaire variability. Factor one, the primary RCTT, explained 25% of the variance in questionnaire variability. Some of the primary RCTT included: performing pull-ups, dead hangs, and utilizing various rock climbing training equipment such as fingerboards, campus boards and rock rings. While factors two, three and four pertained to climbing, explained 30% of the variance. The remaining 7% of the variance was explained by factor five, training from various structures. During study two (the reliability study) nine recreationally active male climbers performed six counterbalanced trials of open-handed and pinch grip weight-assisted pull-ups to failure with 72 hours of recovery. In four trials, the climbers used chalk during open-handed and pinch grip

weight assisted pull-ups, but the remaining two trials, were without chalk. These additional trials allowed for the evaluation of the contribution of chalk to open-handed and pinch grip weight-assisted pull-up performance. Climbers were assisted 50% of body weight for the open-handed and pinch grip pull-ups. No significant differences were found between the open-handed vs. pinch grip or chalked vs. no chalked trials for rating of perceived exertion (RPE), heart rate (HR), perceived recovery scale (PRS) and session-RPE (S-RPE). Intraclass R*s* for test-retest of the open-handed and pinch grip weight-assisted pull-ups were 0.99 and 0.96, respectively. However, Bland-Altman analysis revealed large errors indicating weight-assisted pull-ups using open-handed (95% error range: upper limit 6.34, lower limit -3.90) and pinch grips (95% error range: upper limit 5.35, lower limit -6.91) were only somewhat reliable. Chalk improved performance in both open-handed (mean=22.8 ± 4.53 vs. mean no chalk = 19.7 ± 4.39 reps; $p = 0.006$) and pinch grip (mean = 14.4 ± 4.47 vs. mean no chalk = 9.1 ± 4.83 reps; $p = 0.007$) weight-assisted pull-ups when compared to the non-chalked trials. In the third study, (recovery), each participant performed four counterbalanced trials of closed-handed and open-handed weight-assisted pull ups to failure after 72 hours of recovery. For each trial, participants performed three sets to failure of weight-assisted pull-ups using either the closed-handed or open-handed grip assisted 50% of body weight. Treatments were ~ 20 minutes of passive recovery or ice bags applied, between pull-up sets, to the upper-arm, immediately distal to the shoulder. No differences were found pre- to post- treatments for hand-grip strength, HR, RPE, PRS, and S-RPE or comfort

scales among trials. Participants completed significantly fewer open-handed pull-ups ($p = 0.003$) than closed-handed pull-ups. Ice bag recovery maintained ($p= 0.001$) subsequent open-handed pull-up performance for sets two and three when compared to passive recovery. For closed-handed pull-ups, no differences ($p = 0.31$) were found between ice bag and passive recovery. Overall, results suggest pulling and hanging movements using sport-specific equipment predominate as a primary RCTT. Both the open-handed and pinch grip weight-assisted pull-ups were found to be somewhat reliable, while using chalk with these grips improved weight-assisted pull-up performance. Compared to passive recovery, ice bags were found to be superior for open-handed but not closed-handed pull-ups.

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CHAPTER I

INTRODUCTION

The principle of specificity is an integral part of exercise prescription across a variety of sports. Rock climbers have embraced training tools such as rock rings, fingerboards and indoor climbing walls in order to maintain sport-specific fitness. It was hypothesized that these training tools have a direct impact on a climber's ability to perform. However, in spite of its increasing popularity, research on training and recovery is lacking regarding rock climbing training, possibly because a climber's performance is dependent on a variety of physical abilities and thus difficult to quantify.

Research on recovery modalities between training ascents is sparse. Furthermore, efficacy of common training tools of competitive rock climbers has not been evaluated. The purpose of these investigations is to enhance rock climbing performance by investigating performance measures of climbers on a custom-made device, along with assessing the reliability of the performance measurements. Both physiological and subjective responses were assessed to allow for extrapolating the findings to rock climbers as well as weight lifters desiring to gain muscular endurance of the forearm and hand. It was hypothesized that: i) a variety of hanging and pulling movements would predominate in a rock climber's training regime, ii) the measurements with a custom-made device would be reliable, and chalk would improve open-handed and pinch grip weight-assisted pull-up performance, and iii) that open-handed and closed-handed weight-assisted pull-up performance recovery would be enhanced between sets with ice bag treatment.

CHAPTER II

A SURVEY OF TRAINING TECHNIQUES IN ROCK CLIMBERS

Abstract

The frequency of different rock climbing training techniques (RCTT) was investigated in competitive rock climbers (n = 202; 174 usable). The sample was comprised of both male (n = 117) and female (n = 57) climbers enrolled in the Triple Crown Bouldering Series and ranged from 19 to 62 years of age. A questionnaire on RCTT was created and found to be reliable with a Cronbach alpha of 0.82. Chi square analyses were used to evaluate differences between demographics for each question, while a factor analysis was used to identify key factors. Chi square analyses revealed differences among age groups for three questions, while gender differences also existed for seven questions. Age groups and questions pertaining to using a fingerboard ($p = 0.005$), campus board ($p = 0.05$) and door frames ($p = 0.008$) were significant. The expected vs. observed frequencies, indicated that younger climbers tended to use this type of equipment more frequently compared to older climbers. Responses to questions related to performing pull-ups ($p = 0.035$), using a campus board ($p = 0.029$), and performing extremely difficult routes ($\geq$ 5.10 YDS, $\geq$ V4; $p = 0.02$) were significantly different between sexes. Principal component analysis revealed five factors which explained 62% of the variance in questionnaire variability. Factor one, the primary RCTT, explained 25% of the variance. Some of the primary RCTT included: performing pull-ups, dead hangs, and utilizing various rock climbing training equipment such as fingerboards, campus boards and rock rings. In item-to-total correlations, the following training questions were removed from the principal components analysis: reducing an

individual's body weight to perform pull-ups, weight lifting, specifically training the core, and modes of aerobic cross-training such as running, cycling and swimming. Results suggested male and female climbers train differently; however, using sport-specific equipment and climbing predominate as a primary RCTT regardless of sex.

KEY WORDS: Bouldering, Top-roping, Questionnaire

INTRODUCTION

Currently no published research exists regarding training techniques in the sport of rock climbing (Sheel 2004; Giles, Rhodes and Taunton 2006). This is partly due to the complex and specific nature of the sport, because climbing involves a series of brief, repeated, intermittent, isometric and dynamic exercises using an assortment of grips (Giles et al. 2006). While training, rock climbers often climb at various angles and difficulties while utilizing a variety of grips (Watts 2004; Geus, O'Driscoll and Meeusen 2006). Common rock climbing grips include open-handed grips such as the crimp (also known as the cling), half-crimp, and pinch (Giles et al. 2006; Watts 1996). These grips cannot be readily replicated in standard weight room facilities, so other facilities have been created. Indoor rock training facilities often have training equipment for rock climbing including fingerboards (also known as training boards), campus boards, climbing holds and rock rings (Watts 1996). Furthermore, indoor training facilities allow a climber to maintain fitness levels without driving to an outdoor climbing location.

Unfortunately, climbers' grip strength and endurance cannot be effectively trained in standard weight lifting facilities due to the lack of equipment with open-handed grips. In the weight room, the lifter typically uses closed-handed grips in the supinated, pronated and/or neutral forearm positions while training. Presently, it is difficult to create a structured program that would fulfill the principles of training such as specificity, individual variability, and progressive overload within the sport of rock climbing. After reviewing the literature, investigators have come to the conclusion that a climbing-specific training program does not exist (Giles et al. 2006).

In the absence of specific training programs, the aim of this study was to determine the reliability of an original questionnaire and also common training techniques among recreational rock climbers . Currently the rock climbing training techniques most popular among climbers have not been elucidated.

METHODS

Participants

A total of 202 participants completed a rock climbing training questionnaire; however, due to missing data, only data from 174 participants (117 males, 57 females) ranging from ages 19 to 62 years, were used in the data analysis. Table 1 displays participants' characteristics. Participants were obtained from the Triple Crown Bouldering Series which involved three bouldering competitions that took place in Fall 2009 in North Carolina, Alabama, and Tennessee. Each competition was separated by one month. Competitors age 19 or above were asked to complete a three-page, 40-item, questionnaire on rock climbing training. The study was approved by the local Institutional Review Board.

Instrument utilized

The study was designed as a cross-sectional survey among rock climbers. Rock climbers completed an original training questionnaire developed for this study (Appendix A). Training was defined as anything rock climbers do physically in order to improve rock climbing performance. Standard questions pertaining to training equipment, skill level, and types of climbing were the basic emphases of the survey. For 33 of the 40 questions, a five-point Likert scale was utilized. “Always”, “frequently”, “occasionally”, “seldom”, and “never” were created and defined to determine the prevalence of training regimes; these objective terms were used and defined as: “more than once per week”, “once per week”, “once per month”, “once per quarter”, and “never”, respectively. The remainder of the questions were multiple choice or fill-in-the blank format. The questionnaire allowed for the more thought-provoking questions to be answered first in order to keep subjects’ interest and attention. Questions pertaining to demographics and descriptive characteristics were deliberately placed at the end of the questionnaire. All participants were grouped by age. There were five age groups: 19-22 (n = 46), 23-26 (n = 54), 27-30 (n = 34), 31-34 (n = 18), 35-62 (n = 22), based on resulting sample sizes.

On the advice of both exercise physiologists and climbers, the questionnaire was revised multiple times. Revisions enabled the final questionnaire to be sport-specific and to maximize the clarity of questions before dissemination. The questionnaire was considered reliable with a Cronbach’s alpha of 0.82. Previous literature supports that a Cronbach’s alpha greater than 0.80 is acceptable (Carmines & Zeller 1979), whereas item-to-total correlations below 0.30 are determined to be weak, while those above 0.70 are considered to be strong (Cronk 1999). In general, the questionnaire’s item-to-total correlations were high ($\geq$ 0.30) indicating a high level of reliability. The questionnaire’s standard error of measurement was calculated to be 4.8.

Procedures

All participants were obtained from a convenient sample at the Triple Crown Bouldering Series. The Triple Crown Bouldering Series included Hound’s Ear located in Boone, North Carolina, Horse-Pens-40 located in Steele, AL and Stone Fort in Chattanooga, Tennessee.

The investigator provided writing utensils and questionnaires to all participants and set up a table beside the registration table. To maintain anonymity, no names were recorded. To avoid duplicate submissions the investigator stressed participants should have completed the questionnaire only once during the three climbing competitions.

Statistical Analyses

The survey data from the Triple Crown Bouldering Series were manually entered into Statistical Program for Social Science (SPSS) version 17.0 for Windows and then checked for accuracy. An alpha level of 0.05 was utilized for all data analyses. Gender differences and questionnaire responses were compared utilizing chi-square analyses. A one-way analysis of variance was used to determine differences in types of climbing training by variables such as age, skill level and climbing experience. A principal component factor analysis was utilized to extract key factors to explain the unique variance in questionnaire variability. The most-used climbing grips were assessed by total frequencies.

RESULTS

Table 1 displays descriptive characteristics of the rock climbers. Chi square analyses (Table 2) indicated differences existed among age groups and responses for three questions; and differences also existed between gender and responses for seven questions. Questions related to utilizing finger boards ($x^2(1, N = 174) = 34.313, p = 0.005$), campus boards ($x^2(1, N = 174) = 25.829, p = 0.056$) and hanging or pulling from door frames ($x^2(1, N = 174) = 32.909, p = 0.008$) indicated differences existed between age groups. Responses related to performing pull-ups ($x^2(1, N = 174) = 10.373, p = 0.035$), utilizing a campus board ($x^2(1, N = 174) = 10.801, p = 0.029$), free soloing ($x^2(1, N = 174) = 14.425, p = 0.006$), performing routes between 5.10 and

5.11 Yosemite Decimal Scale, ($x^2(1, N = 174) = 11.690, p = 0.020$), performing routes greater than or equal to 5.12 YDS ($x^2(1, N = 174) = 16.755, p = 0.002$), performing problems between V4 and V7 ($x^2(1, N = 174) = 22.015, p < 0.001$), and performing problems between V8 and V11 ($x^2(1, N = 174) = 19.122, p = .001$) significantly differed between genders.

Principal component analysis allowed for the extraction of five factors explaining the variance in questionnaire variability. The five factors were: factor one-sport-specific training equipment, factor two-climbing routes/problems of varying difficulties; factor three-outdoor endurance climbing, factor four-climbing routes/problems of varying difficulties and factor five-training from various structures. Table 3 displays these five factors which explained 62% of the variance when determining how rock climbers train.

Factor one, using training devices such as fingerboards, campus boards, and rock rings to hang and pull from were used in their climbing training. Factor one explained 25% of the variance. The second factor explained 12% of the variance and was comprised of climbing routes above YDS of 5.12 and between a V4 – V11. The third factor explained 10% of the variance and included types of endurance climbing such as traditional and sport leading. The fourth factor was similar to the second; however the grades of the routes and problems were beginner to intermediate levels (YDS 5.6 – 5.11 / V0 – V3) and explained 8% of the variance. The last factor, various structures, which explained 7% of the variance, entailed that the climbers often would train by hanging or pulling from various structures such as door frames or trees.

Because of low item-to-total correlations, some training questions were removed from the principal components analysis, such as: reducing an individual's body weight to perform pull-ups or dead hangs, specifically training the core (abdominal/erector spinae), weight lifting, training indoors and performing aerobic activities such as running, swimming and cycling. Climbers did not report engaging in these activities to improve their climbing performance.

In regards to the most used grips among rock climbers, the crimp grip, followed by the open-hand grip seemed to be used the most prevalent, whereas the wrap and pinch grips were reported to be used the least among rock climbers in our sample.

DISCUSSION

The aim of the study was to determine climbers' training techniques used to improve rock climbing performance. The study defined training as anything done physically to improve rock climbing performance.

The factor analysis revealed five factors explained 62% of the variance in questionnaire variability. The factors were assigned a subjective name. Factor I was comprised of 5 of the 19 questions which made it into the factor analysis. Factor I (sport-specific training devices) was the primary method in which climbers trained. However factors two, three, and four were all related to climbing problems/routes of varying difficulty. These factors comprised 12 of the 19 questions and explained 30% of the variance in rock climbers' training. The remaining 7% (two questions) comprised of hanging or pulling from various structures. Sport-specific training equipment such as fingerboards, campus boards and rock rings as well as climbing varying problems/routes predominated climber's training.

After examining the expected and observed frequencies of the significant chi-squares analyses, it was concluded that males were more skilled at rock climbing when compared to female rock climbers ($p = 0.02$). Furthermore, males performed pull-ups more often than females ($p = 0.035$) and also trained utilizing a campus board more frequently ($p = 0.029$). This may explain why their climbing performances were superior (Table 1). Flanagan et. al. (2003) suggested that most women cannot perform one pull-up with their body weight. However Grant et. al. (2001) found no differences between males and females for elite, recreational or non-climbers regarding the number of pull-ups performed (Flanagan et. al. 2003, Grant et. al. 2001).

Perhaps one of the most interesting findings was the low item-to-total correlations, which resulted in removal of some of the training questions. These include reducing an individual's body weight to perform pull-ups or dead hangs, specifically training the core (abdominal/erector spinae), weight lifting, training indoors and performing aerobic activities such as running, swimming and cycling. According to our data analyses, climbers do not engage in these activities to improve their climbing performance.

There are no relevant research publications regarding current rock climbing training techniques with which to compare these results. However Mermier et. al. (2000) investigated physiological and anthropometric determinants of rock climbing performance and concluded climbing performance was based on trainable variables such as body fat percentage and grip strength to body mass ratio (Mermier et. al. 2000, Watts et. al 1993). Future research should examine the training techniques of more advanced climbers.

PRACTICAL APPLICATIONS

Rock climbers reported training mostly by climbing, however other simulated rock climbing training equipment such as rock rings, fingerboards, and campus boards were also used. Pulling and hanging movements predominated as a primary training regime. We recommend that athletes can best use climbing and sport-specific equipment to improve climbing performance.

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Tables

Table 1. Mean $\pm$ SD of Anthropometric, Training, and Performance Data (n = 174).

	Men (n = 117)	Women (n = 57)
Age (yrs)	28 ± 8	26 ± 7
Climbing experience (yrs)	4 ± 1	3 ± 1
Climbing ability (V0 – V15)	2 ± 1	1 ± 1

Table 2. Significant x^2 values for (p<.05) frequency differences among age groups and between gender for Rock Climbing Training questions (n = 174).

	Age		
		χ^2	p
Fingerboards		34.3	0.005
Campus boards		25.8	0.056
Door frames		32.9	0.008
	Gender		
		χ^2	*p*
Pull-ups		10.4	0.035
Campus boards		10.8	0.029
Free soloing		14.4	0.006
5.10-5.11 YDS		11.7	0.002
V4 – V7		22	0.000
V8 – V11		19.1	0.001

Table 3 Factor Loadings from a Principal Components Analysis for cumulative % of total variance in responses to similarly grouped training questions (n = 174)

	I	II	III	IV	V
Dead hangs					
Pull-ups					
Fingerboard					
Campus board					
Rock Rings	25.0				
V4 - V7					
V8 - V11					
$\geq$ 5.12		36.7			
Free climb					
Traditional lead					
Sport lead					
Free solo					
Train outdoors			47.1		
5.7 to 5.9					
$\leq$ 5.6					
5.10 - 5.11					
V0 - V3				55.0	
Trees					
Door frames					62.4

CHAPTER III

RELIABILITY OF OPEN- AND PINCH GRIP WEIGHT-ASSISTED PULL-UPS

Abstract

The purpose of this study was to evaluate the reliability of open-handed and pinch- grip weight-assisted pull-ups in recreationally-trained rock climbers. A secondary purpose was to determine if pull-up performance was affected by the use of chalk. Recreationally-active volunteers (n = 9) completed six counterbalanced trials. Four of the trials (two grips each test-retest) were used to determine the reliability of the grips. Two trials were used to determine if performance was affected by using chalk. Each trial included one set of open-handed or pinch grip weight-assisted pull-ups until failure. Each trial used one of two grips each repeated three times (once each grip without chalk). Sets consisted of either the open-handed or pinch-grip pull-ups assisted by 50% reduction of body weight. Heart rate, ratings of perceived exertion, perceived recovery scale and session-RPE were not significantly different ($p > 0.05$) among trials. Intraclass R*s* for test-retest of the open-handed (R = 0.99) and pinch-grip (R = 0.96) weight-assisted pull-ups evidenced reliable values. However Bland-Altman analysis (BA) revealed large errors indicating weight-assisted pull-ups using open-handed (95% error range: upper limit 6.34, lower limit -3.90) and pinch grips (95% error range: upper limit 5.35, lower limit -6.91) were only somewhat reliable. When compared to the non-chalked trials, chalk improved both open-handed (mean=22.8 ± 4.53 vs. mean no chalk = 19.7 ± 4.39 reps; p = 0.006,) and pinch-grip (mean = 14.4 ± 4.47 vs. mean no chalk = 9.1 ± 4.83 reps; p = 0.007) weight-assisted pull-ups. Based upon the ICCR's the measurement was reliable, however the

BA indicated the device was only somewhat reliable. Furthermore chalk improved performance for both open-handed and pinch grips when compared to no chalk trials.

KEY WORDS: Rock Climbing, Grip, Chalk

INTRODUCTION

Resistance training programs have been developed for a variety of sports, however very little is known regarding training techniques in the sport of rock climbing. This is partly due to the complex and specific nature of the sport (Giles et al. 2006). Rock climbers often utilize a variety of open-handed grips when training, including the open, cling, wrap and pinch grips (Watts 1996). Currently, devices for training these open-handed grips are not found in weight training facilities. The standard closed-handed grip, which is often used during dumbbell and Olympic bar exercise movements, does not satisfy the requirement for specificity in grip for climbing.

Landmark studies by Grant et al. (1996 & 2001) investigated the physical performance differences between male climbers and non-climbers, and reported that male climbers were superior in performing pull-ups on a climbing board. No differences between male climbers and non-climbers were found for hand strength, hip flexibility, bent-arm-hang endurance and other descriptive data.

Intermittent isometric handgrip endurance has also been identified as a characteristic of good climbing performance (Ferguson and Brown 1997). Furthermore, Ferguson and Brown (1997) indicated that climbers have an increased vasodilatory capacity in the forearm when compared to untrained counterparts, thus, enhancing acute recovery and endurance capacity, and perhaps aiding in climbing performance.

Many studies have shown that upper-body strength and endurance can be tested by assessing the participant's pull-up ability (Baumgartner and Gaunt 2005). Unfortunately, pull-ups are hard to assess because of zero-scores, so Pate et al. (1987) created the modified pull-up. The modified pull-up has been evaluated for reliability and was found to be a reliable instrument for assessing upper-body strength (Romain and Mahar 2001; Baumgartner and Gaunt 2005; Pate et al., 1993; Engelman and Morrow 1991). Furthermore, reliability of closed-handed weight-assisted pull-ups in untrained middle-aged participants has also been evaluated and found to be reliable (Levinger et. al. 2009).

However, for a weight-assisted pull-up machine, the reliability of both the open-handed and pinch grips has yet to be evaluated using recreationally trained rock climbers, in part because of the lack of a device for open-handed exercise. The primary purpose of this study was to determine the stability of both the open–handed and pinch-grip weight-assisted pull-ups in trained recreational rock climbers using a novel open-handed and pinch grip training device that interfaces with a weight-assisted pull-up machine. A secondary purpose of the current study was to evaluate the impact of chalk on open-handed and pinch-grip weight-assisted pull-up performance. Li et. al. (2001) suggested that chalk does not improve the coefficient of friction between the climber and rock, because it does not dry their hands. Furthermore those investigators supported an alternative means to dry out the hands in order to improve climbing performance (Li et. al. 2001).

METHODS

Participants

The study procedure was approved by the local IRB. Nine healthy male volunteers between 19 and 28 years of age were recruited from an indoor rock-climbing facility. Participants were recreational climbers and had completed a standard bouldering problem between V1 and V7 based on the V scale in the past twelve months and climbed indoors or outdoors an average of once per week for at least six months (Grant et. al. 1996). The Physical Activity Readiness Questionnaire (PAR-Q) and a health screening questionnaire were used to evaluate health risks. A dichotomized 'yes' or 'no' format was utilized for the PAR-Q. If the subject answered 'yes' to any of the PAR-Q questions, they were excluded from the study. All participants completed an informed consent and training questionnaire to determine climbing history (Heyman et al. 2009). Participants were asked to maintain their normal dietary habits throughout the study and not to engage in any form of upper-body exercise during the study protocol (McLester et. al. 2003; Buckner 2009).

Anthropometric Assessments and Familiarization

After completing an informed consent, PAR-Q, health status questionnaire, and training history questionnaire, body weight, height, and body fat percentage were assessed. Height and weight were assessed on a scale with stadiometer (Detecto, Webb City, MO). Each participant's body fat percentage was estimated based on age and the sum of three skin-fold sites (chest, abdomen, and thigh) (Pollock et al. 1980) utilizing skin-fold calipers (Lange, Cambridge, MD). After hand strength was assessed via hand dynamometer (Country Technology, Gays Mills, WI), participants performed two sets of 10 repetitions of both open-handed and pinch grip pull-ups assisted by 50% of body weight (Paramount Fitness Corp., Los Angeles, CA) to become familiar with the protocol.

Experimental Protocol

Hand Strength Assessments

Immediately after anthropometric data were assessed, the participants were tested via a hand-grip dynamometer (Country Technology, Gays Mills, WI) for hand-grip/forearm strength.

Both hands were tested and recorded, and the dominant hand noted. The participant was sitting down in an arm chair, while the elbow joint was flexed at a 90^{o} angle. Unlike many hand dynamometer assessments, the dynamometer was placed with the dial face perpendicular to the table, with the face of the dynamometer displayed toward the participant. The participant's thumb was always placed on the fixed portion of the dynamometer frame, and the dynamometer was flipped depending on which hand was being evaluated. The participant grasped the gauge of the dynamometer (the moveable aspect of the device) with the four of the fingers, while the thumb braced against the outside frame of the dynamometer. This was done to mimic the pinch grip. To assess strength, the hand-grip dynamometer was squeezed maximally three times by the participant for one second per repetition. Each maximal squeeze was separated by 15 seconds. Chalk was available to reduce slipping (Giles et al. 2006; Bishop 2008).

Open-Handed and Pinch-Grip Exercise Assessments

At least 72 hours after the familiarization stage, each participant performed either open-handed or pinch-grip weight-assisted pull-ups to failure. In order to utilize the open-handed and pinch grips during the pull-up, a custom device was built to allow attaching climbing holds could either be used as an open-handed or pinch grip (Nicros,Inc., St. Paul, MN) to the weight-assisted chin/dip machine (Paramount Fitness Corp., Los Angeles, CA). Attaching the custom-made device to the machine allowed for weight assisted pull-ups to be performed using open-handed and pinch-grips.

Each of the six trials were counterbalanced (based on grip), so participants performed one set of body-weight-assisted pull-ups using either the open-handed or pinch-grip at a cadence of 20 pull-ups per minute until volitional failure. The set was terminated if the participant failed to complete the entire range of motion for two consecutive pull-ups. Each trial was separated by a

72 hours to allow for recovery. Two trials, one using the open-handed and one the pinch grip were done without chalk. This allowed evaluation of the effect of chalk on open-handed and pinch grip weight-assisted pull-up performance.

Before each trial, participants reported ratings of perceived recovery using the perceived recovery scale (Laurent et. al. *in press*). A five-minute passive recovery was permitted between the warm-up set and test set to allow acute recovery. Warm-up set comprised of the participant performing 10 pull-ups using the open-handed or pinch grips using only 30% of body weight. Participants reported ratings of perceived exertion (RPE) (Borg et al., 1987) and heart rate was recorded (Polar USA, Ann Arbor, MI) pre- and post- set. S-RPE utilizing the OMNI scale was recorded approximately 20 minutes post-training session (Robertson, 2000). This provided a difficulty rating for the entire training workout (Foster et al., 2001; Laurent et al., *in press*). Furthermore, participants' comfort in using the custom-made device was measured on a 100-mm hedonic scale.

The assistance provided by the pull-up machine for open-handed and pinch grip pull-ups was 50% of the participant's body weight rounded to the nearest 1.1 kg. This percentage was chosen during pilot testing. All participants completed six-counterbalanced trials. Each experimental trial involved performing a set to failure using either the open-handed or pinch-grip custom climbing hold. Chalk was used during all trials, except two (once for each grip) of the six experimental trials. Each set began with the participant supporting 50% of body weight with full elbow extension. There was no time limit. All pull-ups were done at a fixed width of 70 cm.

Analysis

The Statistical Package for Social Sciences (SPSS, Inc., Chicago, IL) and Microsoft Excel (2007) were used to analyze the data. Utilizing SPSS, repeated measures one-way ANOVAs were used to determine differences between RPE, S-RPE, HR, and the total number of open-handed and pinch-grip pull-ups (with and without chalk). Bonferroni analyses were performed to examine post-hoc differences. Intra-class reliability coefficients comparing repeated trials for each grip and total number of pull-ups among participants in all four trials were also computed. Using Microsoft Excel Bland–Altman analyses were performed to evaluate the error in the repeated measurements. An alpha value was set at 0.05.

RESULTS

Table 1 displays descriptive characteristics of the rock climbers. Intraclass R*s* for test-retest of the open-handed and pinch grip weight-assisted pull-ups evidenced reliable R values. However, Bland-Altman analyses revealed large errors indicating weight-assisted pull-ups using open-handed (95% error range: upper limit 6.34, lower limit -3.90; Figure 1) and pinch grips (95% error range: upper limit 5.35, lower limit -6.91; Figure 2) were only somewhat reliable.

In this study, the chalked-open-handed grip allowed the participants to perform more pull-ups (22.83 ± 4.53, 14.39 ± 4.47; $p = 0.001$) when compared to the chalked-pinch grip, respectively (Figure 3). Chalk increased both open-handed ($p = 0.006$) and pinch-grip ($p = 0.007$) weight-assisted pull-up repetitions when compared to the non-chalked trials (Figures 4, 5). Figure 6 indicates overall comfort was significantly greater between chalked-open-handed vs. chalked-pinch grip weight-assisted pull-ups. No differences were found for joint comfort and joint strain between grips, with or without chalk ($p > .05$). Rating of perceived exertion (RPE), heart rate (HR), perceived recovery scale (PRS) and session-RPE (S-RPE) were not significantly different ($p > .05$) between trials.

DISCUSSION

The primary aim of this study was to examine the reliability for weight-assisted pull-ups utilizing open-handed and pinch grips. A secondary aim was to investigate whether chalk would improve weight-assisted pull-up performance using the open-handed and pinch grip.

According to most scientific standards the open-handed and pinch grips were reliable because of the high ICCR, however, the relatively large error determined by the Bland-Altman analysis suggests a lower reliability. The test-retest intraclass R*s* of the open-handed and pinch grips (R 0.99 and 0.96, respectively), suggest a highly reliable instrument. However, the Bland-Altman analyses displayed large upper and lower limit errors for both the open-handed and pinch grips, suggesting these grips were only somewhat reliable.

Large errors shown by the Bland-Altman analysis could be related to the sample of participants. Participants were told not to engage in any form of upper-body exercise during the protocol; however, the data collection took place during the spring and thus during climbing competitions. Despite that the 72 hours between sessions should be sufficient time for a complete recovery for this age group (McLester et. al. 2003, Buckner 2009); the performance variance between sessions could be attributed to poor nutrition or lack of sleep (McLester et. al. 2003, Buckner 2009).

We brought two participants back for further testing after the final experimental session to do two more pinch grip sessions. These two participants were chosen to perform the pinch grip because of the large differences shown between pinch grip test-retest sessions. Both participants went through test-retest pinch grip sessions. One participant did the exact same number of pinch grip pull-ups both times while the second participant varied by five pinch grip pull-ups (11 and 16). Upon discussing with the second participant why he would vary by five pull-ups, he informed the investigator that he was tired from lack of sleep.

There are no prior research publications using the open-handed or pinch grips in weight-assisted pull-ups with which to compare our present results. Weight-assisted pull-ups using a variety of grips could allow for individuals who cannot support their entire body weight while climbing could use this device to progress into the sport of rock climbing.

The secondary purpose of the study was to determine if chalk would improve open-handed and pinch grip performance. Li et al. 2001 investigated the use of chalk, which is often used by rock climbers. The results of that study indicated that chalk reduced the friction coefficient between the climber's hand and rock (slate, sandstone, and granite) and concluded rock climbers should not use chalk. However, in the present study, chalk improved performance for both open-handed and pinch grip weight-assisted pull-ups. This may be attributed to some improved friction between the climber and climbing hold. It should be noted that the climbing holds we used were made of plastic, and therefore unlike real rock. The long popularity of chalk use among climbers is some testimony to its utility.

This study indicated that our participants performed fewer pinch-grip pull-ups (Figure 3) and also reported that the pinch grip was more uncomfortable (Figure 6) compared to the open-handed grip. This should be interpreted with caution. Open-handed grips, also known as 'slopers', slope differently, and also come in different shapes and sizes. The pinch grip is described by climbers as being more difficult when the climbing hold is smaller and perpendicular to the ground compared to when the climbing hold is larger and angled. In support of these statements, Piscopo (1974) found that the mechanical aspects of performing a pull-up were dependent upon two lines of pull, direct and twisting. The study indicated that during elbow flexion of a supinated forearm, the mechanical advantage becomes maximized when the direct line of pull from the biceps brachii is created (Piscopo, 1974). Furthermore, Gabbard et al (1981) found that a chin-up (hands supinated) allowed the participant to do more chin-ups when compared to performing a pull-up (hands pronated). Piscopo (1974) further supported the findings of Gabbard et al (1981) and concluded that during elbow flexion of the supinated forearm, the direct line of pull from bicep tendon to the bicep allowed the participants to perform more chin-ups (Piscopo 1974). The results of the current study support those previous findings. Both the open-handed and pinch–grips required the participant to perform the pull-up while the forearm is pronated. However, the tendons of the wrist to the fingers are in direct lines of pull only during the open-handed grip. For the pinch-grip, the climbing hold was attached to the device perpendicular to the ground, which required the participant to twist the lines of pull in the tendons of the wrist and fingers, thus placing the participants at a mechanical disadvantage from the start.

Furthermore, we observed no difference between pre- and post- trial for pinch grip strength. We attributed this is to the fact rock climbers having an increased ability to recover from 'sustained and rhythmic isometric exercise' due to improved vasodilatory capacity of the forearm and hand (Ferguson et. al. 1997). Because of climbers' enhanced vasodilatory capacity, perhaps they had sufficient recovery between pre- and post- pinch grip strength sessions, and therefore no difference was detected.

In summary, the performance measurement was generally reliable; however, caution should be used due to the large errors demonstrated by the Bland-Altman analyses. Furthermore, we recommend that chalk be used to increase performance under these conditions. Future research should investigate the training differences between the closed-handed, open-handed, and pinch grips, and continuing to investigate if using chalk would improve climbing performance on real rock rather than climbing holds made of plastic which are specifically designed for indoor climbing.

PRACTICAL APPPLICATIONS

The open-handed and pinch-grip training device utilized in this study was reliable and could allow for a structured, sport-specific, training program for rock climbers. The new device could also aid individuals who are trying to improve hand-grip strength and endurance while performing a compound movement within the weight room, rather than using the standard closed-handed grip. Utilizing the open-handed grip would enable trainers and coaches to satisfy the basic principles of training and stimulate more musculature of the hand and forearm for not only rock climbers but a variety of populations. Furthermore, chalk improved open-handed and pinch-grip performance. Climbers and weight lifters training to improve their open-handed and pinch grips should continue to use chalk when training and also during competitions.

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Tables

Table 1. Mean ± SD for anthropometric, training and performance data (n = 9).

Age (yrs)	22.0 ± 3.0
Height (m)	1.8 ± 0.1
Weight (kg)	75.8 ± 8.0
Body fat (%)	13.4 ± 5.6
Months trained (months)	22.0 ± 11.6
Days trained per month (days)	9.4 ± 5.3
Hours trained per week (hrs)	4.4 ± 3.5
Dominant hand pinch strength (kg)	6.8 ± 2.2
Non-dominant hand pinch strength (kg)	6.1 ± 1.8

Figures

Figure 1. Bland-Altman Analyses: Observed difference between open-handed session one and session two (n = 9).

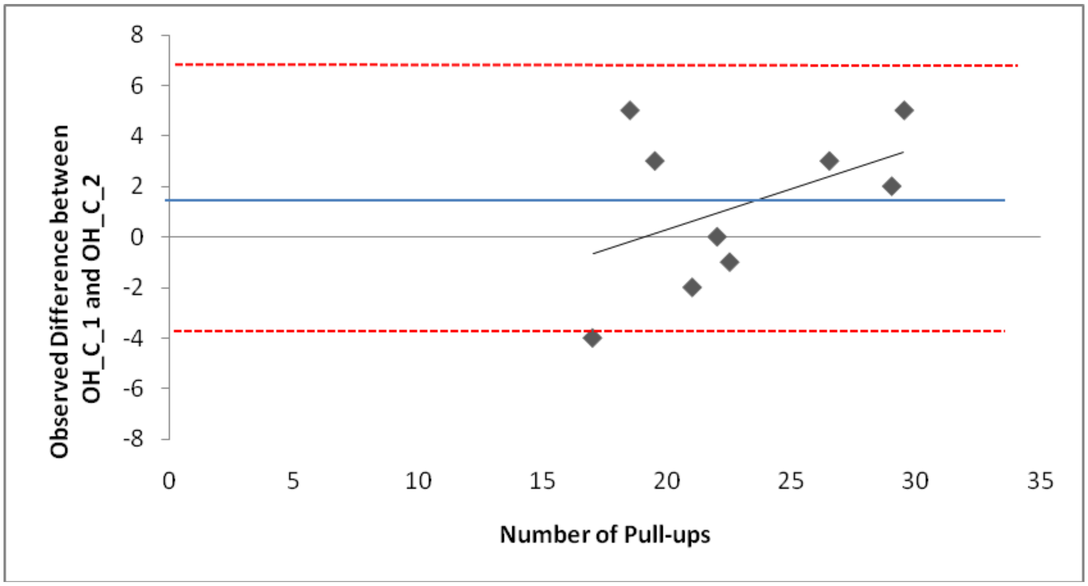


Figure 2. Bland-Altman Analyses: Observed difference between pinch grip session one and session two (n = 9).

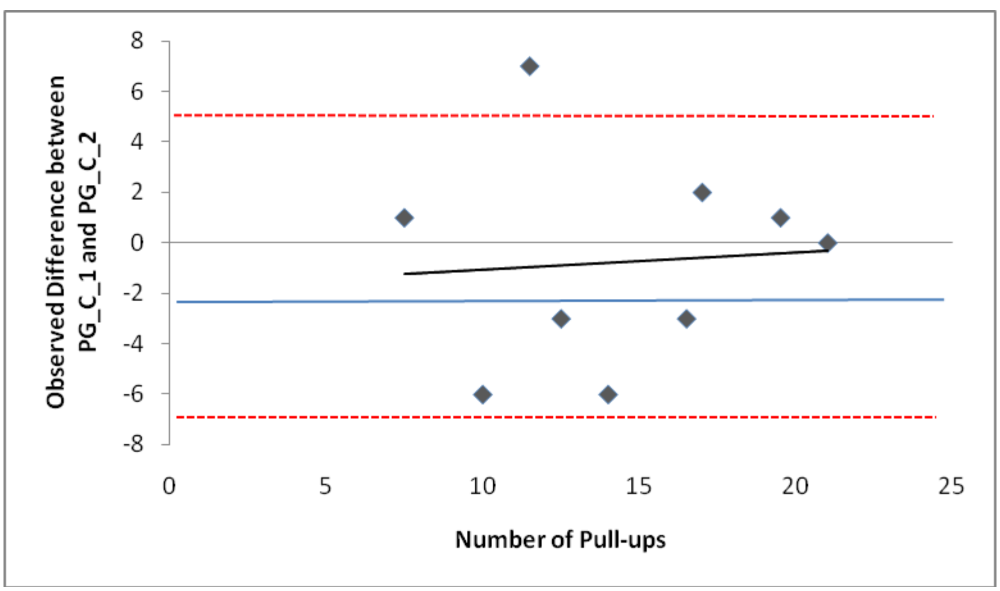


Figure 3. Average (± SD) open-handed and pinch grip weight-assisted pull-ups (sessions performed with chalk; *p < .05; n = 9).

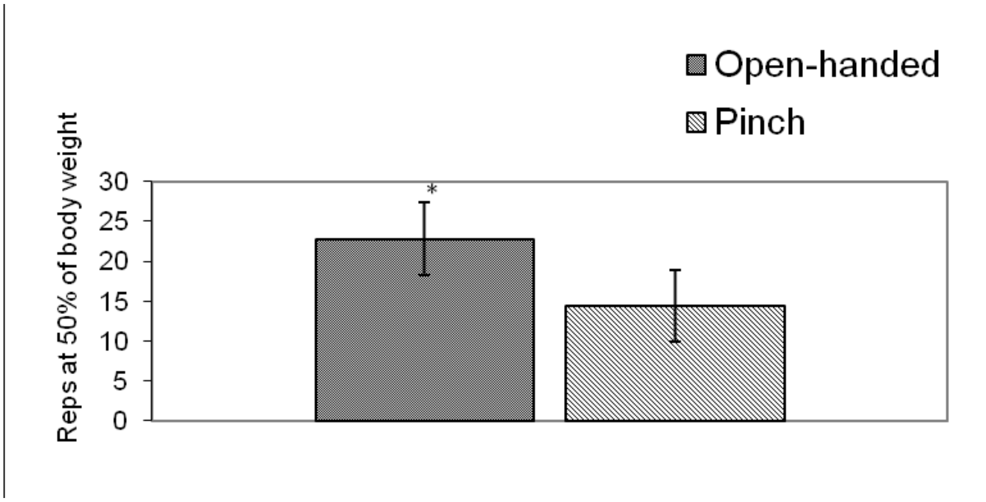


Figure 4. Average (± SD) open-handed weight-assisted pull-ups with and without chalk (*p < .05; n = 9).

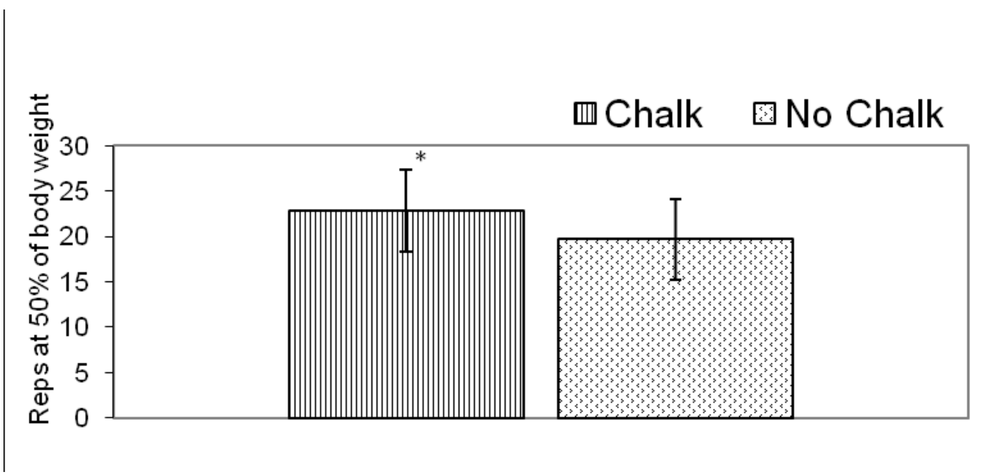


Figure 5. Average (± SD) pinch grip weight-assisted pull-ups with and without chalk (*p < .05; n = 9).

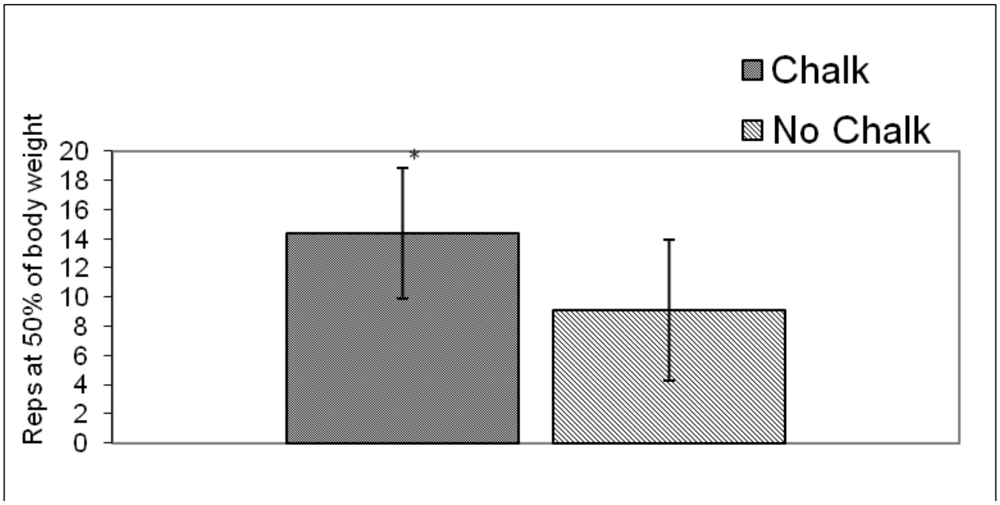
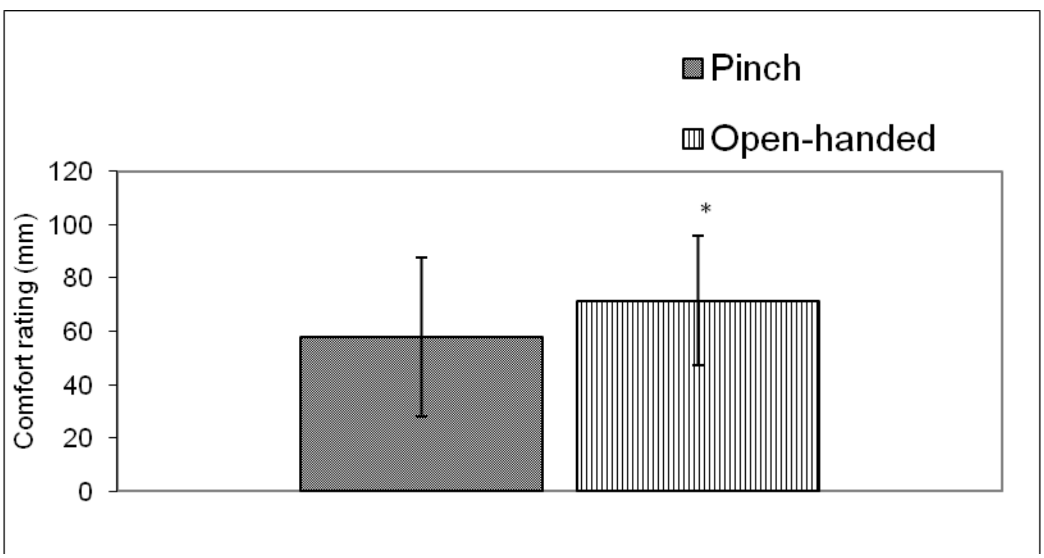


Figure 6. Average (± SD) 100-mm scale to measure perceived overall comfort of pinch grip and open-handed-grip weight-assisted pull-ups (sessions performed with chalk; *p < .05; n = 9).



CHAPTER IV

EFFECT OF TWO RECOVERY METHODS ON REPEATED CLOSED- HANDED AND OPEN-HANDED WEIGHT-ASSISTED PULL-UPS

Abstract

The purpose of this study was to examine two recovery modalities (passive and ice bag treatment) on closed-handed and open-handed weight-assisted pull-ups in recreationally-trained rock climbers. Healthy and recreationally-active volunteers ($n = 9$) completed four counterbalanced trials. Trials included three sets (each set separated by approximately 20 minutes with passive and ice recovery) each of closed-handed and open-handed (each trial separated by 72 hours) weight-assisted pull-ups until failure assisted by support of 50% of body weight. Heart rate (HR), ratings of perceived exertion (RPE), and session-RPE (S-RPE) were also assessed. No differences were found for hand-grip strength pre- and –post trial. Also there were no differences found for HR, RPE, Perceived Recovery Scale, S-RPE, or comfort ratings among trials. The number of open-handed pull-ups (mean = 18.93 ± 4.57) was smaller than closed handed pull-ups (mean = 33.52 ± 13.55) ($p < 0.001$). Ice bag recovery maintained subsequent open-handed pull-up performance for sets two (mean = 22.33 ± 5.45) and three (mean = 22.33 ± 4.92) when compared to the third set using passive recovery only (mean = 17.22 ± 5.67) ($p = 0.004$, $p = 0.003$, respectively). No differences ($p = 0.31$) were found for closed-handed pull-ups between ice bag vs. passive recovery trials. Results indicated that ice bag recovery after open-handed weight-assisted pull-ups maintained subsequent performance

relative to passive recovery, but failed to maintain closed-handed grip weight-assisted pull-up performance.

KEY WORDS: Rock climbing, Grip training, Resistance training, Ice

INTRODUCTION

Over the past 20 years, the number of climbing facilities in the United Kingdom alone increased six-fold (Giles et. al. 2006). Despite the increase in popularity, limited research exists in the sport of rock climbing. Both climbing training and recovery between climbing bouts are not well understood. Only three studies have investigated the effects of recovery upon climbing (Heyman et al., 2009; Watts et al., 2000, and Draper et al., 2006).

Moreover, the study by Heyman et al. (2009) is the only one to investigate a variety of recovery modalities on subsequent climbing performance. They evaluated the effects of cold water immersion, electromyostimulation, and passive or active recovery (leg cycling) between climbing bouts and found that both cold water immersion and active recovery maintained climbing performance. Climbing often activates smaller musculature of the hand and forearm such as the brachioradialis and flexor digitorum and causes pain of the forearm when climbing to volitional failure (Koukoubis et al., 1995, Heyman et al., 2009). Furthermore cold water immersion has also been shown to improve writing performance in individuals who often experienced writer's cramps (Pohl et al. 2002). Though these mechanisms are not completely understood, it appears that cold water immersion provides an analgesic effect on the forearm and lowers hand temperature, causing localized vasoconstriction and lowering muscle temperature, and thereby provides relief from the acute inflammation from muscle damage (Heyman et al. 2009).

Furthermore, active recovery involving low intensity leg-cycling maintained subsequent climbing performance (Heyman et al., 2009). While Watts et al. (2000) reported active recovery accelerated blood lactate removal after climbing when compared to passive recovery, subsequent climbing performance was not evaluated.

The aim of this study was to determine if iced recovery between sets of closed-handed and open-handed weight-assisted pull-ups would improve or maintain performance in recreationally-trained rock climbers. It was hypothesized that using ice bag treatment as a recovery method compared to passive recovery would improve or maintain both closed-handed and open-handed weight-assisted pull-ups.

METHODS

Participants

The study procedure was approved by the local IRB. Nine healthy male volunteers between 19 and 28 years of age were recruited from an indoor rock climbing facility. Participants were recreational climbers and had completed a standard bouldering problem between V1 and V7 based on the V scale in the past twelve months and climbed indoors or outdoors an average of once per week for at least six months (Grant et. al. 1996). Physical Activity Readiness Questionnaire (PAR-Q) and a health screening questionnaire were used to determine health risks. A dichotomized 'yes' or 'no' format was utilized for the PAR-Q. If the subject answered 'yes' to any of the PAR-Q questions, they were excluded from the study. According to the risk stratifications set forth by the American College of Sports Medicine (ACSM) all participants were of low risk when utilizing the data collected from the current study.

All participants completed an informed consent and training questionnaire to determine climbing history (Heyman et al. 2009). Participants were asked to maintain their normal dietary habits throughout the study and not to engage in any form of upper-body exercise during the study (McLester et.al. 2003; Buckner 2009).

Anthropometric Assessments and Familiarization

After completing the aforementioned tasks, body weight, height, and body fat percentage were assessed. Height and weight were assessed on a scale and stadiometer (Detecto, Webb City, MO). Each participant's body fat percentage was estimated based on age and the sum of three skin-fold sites (chest, abdomen, and thigh) (Pollock et al. 1980) utilizing skin-fold calipers (Lange, Cambridge, MD). After hand strength was assessed via a hand dynamometer (Country Technology, Gays mills, WI), participants performed two sets of 10 repetitions of both open-handed and closed-handed grip pull-ups assisted by 50% of body weight (Paramount Fitness Corp., Los Angeles, CA) to become familiar with the protocol.

Experimental Protocol

Hand Strength Assessments

Immediately after anthropometric data were assessed, the participants were tested via a hand-grip dynamometer for hand grip/forearm strength. Both hands were tested and recorded, and the dominant hand noted. The participant was sitting down, upright in an arm chair for support, while the elbow joint was flexed at a 90^{o} angle. Unlike many hand dynamometer assessments the dynamometer was placed with the dial face perpendicular to the table, with the face of the dynamometer displayed toward the participant. The participant's thumb was always placed on the fixed portion of the dynamometer frame, and the dynamometer was flipped depending on which hand was being evaluated. The participant grasped the movable arm of the dynamometer with the four of the fingers, while the thumb braced against the immovable part of the dynamometer. This was done to mimic the pinch grip. To assess strength, the hand-grip dynamometer was squeezed maximally three times by the participant for one second per repetition. Each maximal squeeze was separated by 15 seconds. Chalk was available to reduce slipping (Giles et al. 2006; Bishop 2008).

Closed-handed, and Open-handed Exercise Assessments

At least 72 hours after the familiarization session, each participant performed four experimental trials consisting of either closed-handed or open-handed weight-assisted pull-ups to failure using one of the recovery modalities between sets. The four testing sessions were counterbalanced. Participants performed a warm-up set of 10 repetitions at 30% of body weight and then performed three sets of body-weight-assisted (at 50% body weight) pull-ups using either the closed-handed or open-handed grips at a cadence of 20 pull-ups per minute until volitional failure. A nineteen-minute recovery was permitted between each set to allow acute recovery (Heyman et al., 2009).

Two types of recovery were used. Passive recovery required the participant to remain in a seated position with the upper limbs along the sides of the body (Heyman et al., 2009). Ice bag treatment required the participant to have ice bags attached to the arms distal to the shoulder. Ice bag treatment was terminated at 17 minutes. For the remaining 2 minutes, participants were seated and underwent a short passive recovery allowing them to prepare for the next set (time to dry off and chalk up).

After each set, the participants were asked to provide ratings of perceived exertion (RPE) (Borg et al. 1987) and heart rate (HR; Polar USA, Ann Arbor, MI) was recorded prior to, and immediately after, each set (Robertson 2000). PRS was also recorded before each trial began.

Approximately 20 minutes after each training session, participants provided a session RPE (S-RPE) using the OMNI scale. This provided a difficulty rating for the entire training workout (Foster et al., 2001; Laurent et al., *in press*). Additionally, participants used a 100-mm hedonic scale to rate their comfort using the custom made pull-up handgrip device.

In order to utilize the open-handed grip during the pull-up, a custom-built device was used to attach climbing holds (Nicros, Inc., St. Paul, MN) to the weight-assisted chin-up machine (Paramount Fitness Corp., Los Angeles, CA). Attaching the custom-made device to the machine allowed for weight assisted pull-ups to be performed using an open-handed grip.

The percentage of body weight assisted (i.e. the amount of weight supported) for closed-handed and open-handed pull-ups was 50% of the participant's body weight and based on pilot testing.

All participants completed each set to failure using either the closed-handed (pronated) grip or the open-handed grip. The amount of weight assisted by the machine was rounded to the nearest 1.1 kg. Each set began with the participant supporting the percentage of body weight assigned with full elbow extension. The set was terminated if the participant failed to complete the entire range of motion or could not keep cadence for two consecutive pull-ups. There was no time limit. All pull-ups were done at a fixed width of 70 cm.

Analyses

The Statistical Package for Social Sciences (SPSS, Inc., Chicago, IL) was used to analyze the data. Repeated measures one-way ANOVAs were used to determine group mean differences between trials in RPE, PRS, S-RPE, HR, total number of closed-handed and open-handed pull-ups, total number of closed-handed and open-handed pull ups using the two recovery modalities and overall comfort based on an 100-mm scale. Bonferroni post hoc comparisons were performed to examine differences between groups. All data were displayed as means and standard deviations. An alpha value was set at 0.05.

RESULTS

Table 1 displays descriptive characteristics of the rock climbers. No differences were found between trials for pinch-grip hand strength pre- and post- each trial. Also no differences were found for HR, RPE, PRS, S-RPE, or ratings of comfort among trials. Climbers performed fewer open-handed pull-ups (mean = 18.9 ± 4.57) compared to closed-handed pull-ups (mean = 33.5 ± 13.55) ($p = 0.003$). Ice bag recovery maintained subsequent open-handed pull-up performance for sets two (mean = 22.3 +- 5.45) and three (mean = 22.3 +- 4.92) when compared to the third set using passive recovery only (mean = 17.2 +- 5.67) ($p = 0.004$, $p = 0.003$, respectively) (Figure 2). Ice bag recovery did not maintain closed-handed performance when compared to passive recovery only ($p > 0.05$).

DISCUSSION

The purpose of this study was to determine if ice bag recovery would improve or maintain subsequent open-handed and closed-handed weight-assisted pull-up performance compared to passive recovery. Ice bag recovery maintained open-handed weight-assisted pull-up performance compared to passive recovery. However this was not true for closed-handed performance, wherein performance after ice treatment during recovery was no different from passive recovery ($p = 0.31$).

Perhaps the ice bag recovery treatment was effective for open-handed, but not for closed-handed performance because of the musculature that was cooled between the pull-ups sets. Ricci et. al. (1988) investigated which muscles were activated during a closed-handed pull-up using electromyography and found that the large musculature of the shoulder and back (infraspinatus, teres major, upper pectorialis major, biceps brachii, and latissimus dorsi) became activated throughout the full range of motion. Koukoubis et. al. (1995) investigated the electromyography of a climber performing pull-ups on a fingerboard using only one grip. The authors did not mention which grip was used; however, participants performed the pull-ups using the finger tips of both hands. It could be logically concluded that this was an open-handed grip. The authors concluded that the main muscles activated during the pull-up were the brachioradialis, and the flexor digitorum superficialis. It seems that because in the present study ice bags were placed only distal to the shoulder, therefore, the upper pectorialis and the latissimus dorsi, the main muscles involved in a closed-handed pull-up were never cooled between sets and therefore the ice bags failed to maintain or improve closed-handed performance.

Heyman et al. (2009) evaluated four types of recovery methods and allowed the climber to climb until volitional exhaustion. The four types of recovery were: passive recovery, lower-body cycling, electromyostimulation of the forearm, or cold water immersion of the entire arm. Twenty minutes of recovery separated the two climbing ascents. Results suggested that both active recovery and cold water immersion could be used effectively to maintain climbing performance between bouts of exercise. However, passive and electromyostimulation failed to maintain climbing performance, during the second ascent.

Watts et al. (2000) also investigated passive vs. active recovery and discovered that leg cycling allowed the climbers to return back to baseline blood lactate levels 20 minutes post climb compared to passive recovery which took 30 minutes for blood lactate levels to return to baseline. However, climbing performance was not evaluated. Draper et. al. 2006 reported similar findings using five climbing trials and suggested that active recovery was superior to passive recovery. Whereas, Green et. al. (2010) reported that recoveries such as vibration and ‘shaking out’ (energetically shaking the hands) failed to maintain or improve climbing performance.

Our study supports research suggesting that some recovery modes aid performance, at least for open grips (Heyman et al. 2009, Watts et al. 2000, Draper et.al 2006, Green et. al 2010). Recoveries such as ice bags maintained repeated open-handed pull-ups performance, in the same way that cold water immersion (Heyman et al 2009) and leg cycling (Heyman et al 2009) maintained climbing performance.

PRACTICAL APPLICATIONS

During bouldering competitions, rock climbers have approximately eight hours to complete a number of routes, called “problems” and record scores. Most of the time only 10 problems are scored, so the more difficult the problem the more points the climber will receive. There is a strategy to winning a bouldering competition and the use of ice bags between ascents could keep the climber recovered enough to maintain climbing performance. Although cold water immersion and leg cycling have also been effective in maintaining climbing performance, (Heyman et al 2009) these methods are not as practical as ice bags during an outdoor competition.

Depending on the cycle of training, climbing coaches may want to use ice bags on athletes during a training session to allow more work to be done within a given time frame. This might allow the climbers to ‘overreach’ what they normally would be able to handle, and thus increase useful training volume.

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Tables

Table 1. Mean ± standard deviation of anthropometric, training and performance characteristics (n = 9).

Age (yrs)	22.0 ± 1.7
Height (m)	1.8 ± 0.1
Weight (kg)	73.1 ± 14.5
Body fat (%)	12.0 ± 6.1
Months trained (months)	35.7 ± 17.7
Days trained per month (days)	10.0 ± 5.7
Hours trained per week (hrs)	5.8 ± 4.1
Dominant hand pinch strength (kg)	7.2 ± 1.6
Non-dominant hand pinch strength (kg)	6.1 ± 2.0

Figures

Figure 1. Average (± SD) closed-handed weight-assisted pull-up repetitions performance decrement scores across all three sets to failure during two recovery modalities (PR = Passive Recovery; $p > 0.05$; $n = 9$).

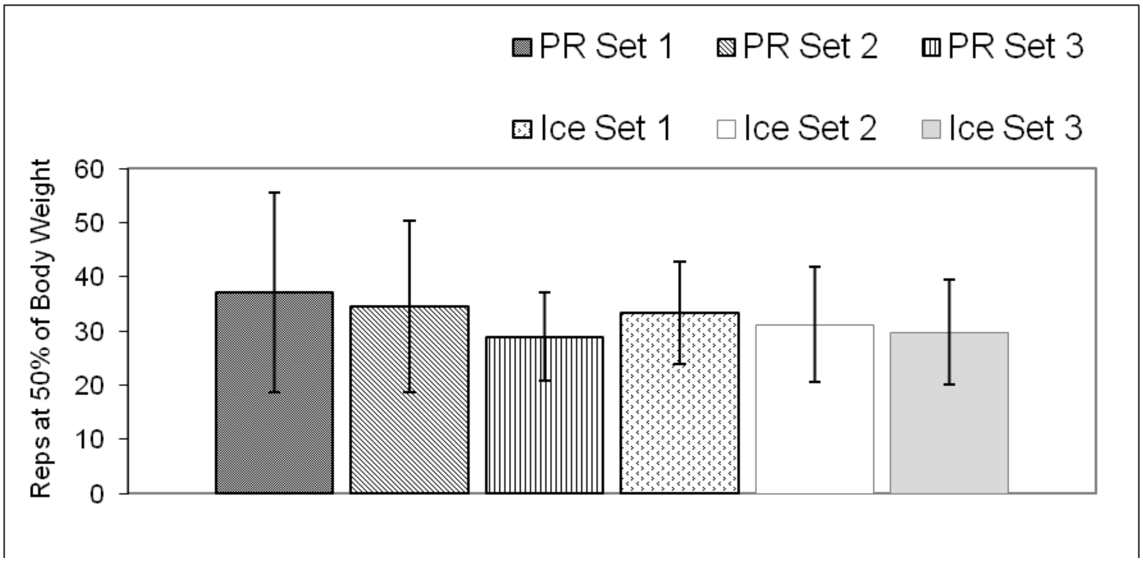
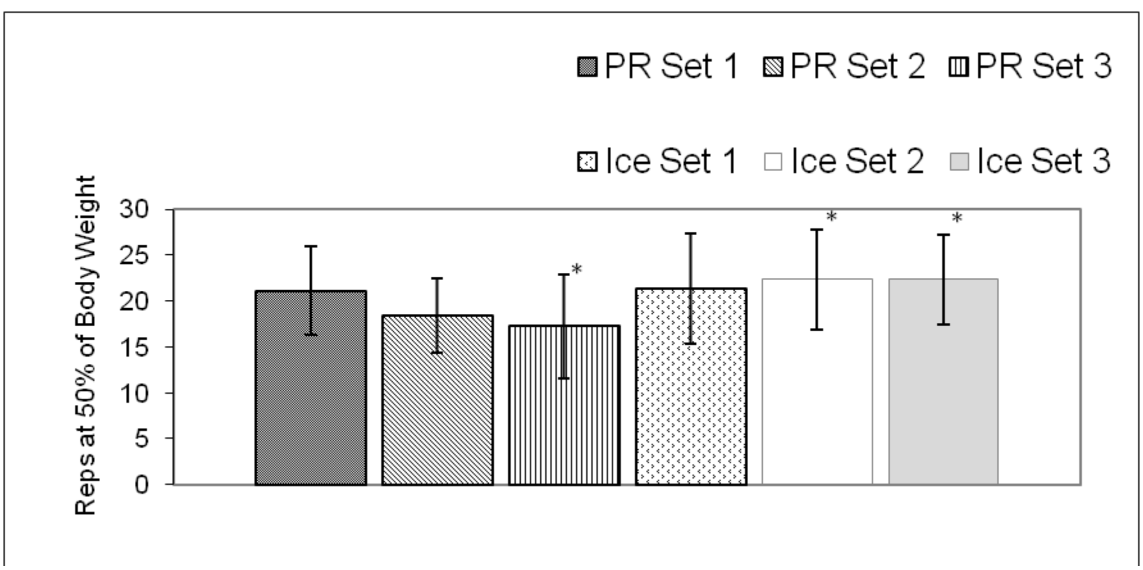


Figure 2: Average (± SD) open-handed weight-assisted pull-up repetitions performance decrement scores across all three sets to failure during two recovery modalities (PR = Passive Recovery; $p < 0.05$; $n = 9$)



CHAPTER V

CONCLUSIONS

Conclusions from study one indicated rock climbers' often climb a variety of routes and problems and utilize sport-specific equipment such as fingerboards, campus boards, and rock rings to improve climbing performance. Study two specified weight-assisted pull-ups using open-handed and pinch grips were considered reliable based on ICCR standards alone; however Bland-Altman Analysis revealed a large amount of error between test-retest trials. Participants using chalk while performing open-handed and pinch grip weight-assisted pull-ups performed significantly more pull-ups when compared to using no chalk. Thus we recommend that climbers continue to use chalk to prevent slipping and improve climbing performance. While study three revealed ice bag treatment between open-handed weight-assisted pull-ups maintained performance compared to passive recovery alone, and thus this study supports using ice as a recovery aid between climbing bouts to enhance rock climbing performance.

Appendix

Appendix A

ROCK CLIMBING TRAINING SURVEY

The purpose of this survey is to determine training techniques in rock climbers. Training is defined as anything you do physically in order to improve your rock climbing performance.

Please answer by putting an “X” in the appropriate box. You may only provide one “X” for each question. You may be uncertain how to answer, but please do your best anyways.

Questions 1 – 34: Answers Defined:
Never = Never, Seldom = once per quarter, Occasionally = once per month, Frequently = once per week, Always = more than once per week

1. How often do you perform pull-ups?
   1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

2. How often do you perform dead hangs?
   1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

3. How often do you use rock rings?
   1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

4. How often do you use a fingerboard/hangboard?
   1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

5. How often do you use a chair or stool to reduce your body weight when performing pull-ups?
   1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

6. How often do you use a chair or stool to reduce your body weight when performing dead hangs?
   1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

7. How often do you use a campus board?
   1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

8. How often do you use indoor rock climbing facilities (artificial rock walls)?
   1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

9. How often do you lift weights?
   1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

10. How often do you specifically workout your core (stomach/back)?
   1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

11. How often do you hang/pull from door frames?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

12. How often do you hang/pull from trees?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

13. How often do you train *indoors*?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

14. How often do you train *outdoors*?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

15. How often do you boulder?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

16. How often do you top-rope?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

17. How often do you traditional lead?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

18. How often do you free climb?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

19. How often do you sport lead?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

20. How often do you free solo?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

21. How often do you climb a Yosemite Decimal System route up to 5.6?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

22. How often do you climb a Yosemite Decimal System route between 5.7 and 5.9?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

23. How often do you climb a Yosemite Decimal System route between 5.10 and 5.11?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

24. How often do you climb a Yosemite Decimal System route of or above a 5.12?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

25. How often do you climb a ‘V’ grade problem up to V3?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

26. How often do you climb a ‘V’ grade problem between V4 and V7?
1 ☐ Never 2 ☐ Seldom 3 ☐ Occasionally 4 ☐ Frequently 5 ☐ Always

27. How often do you climb a 'V' grade problem between V8 and V11?
1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

28. How often do you climb a 'V' grade problem of or above a V12?
1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

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29. How often do you walk/hike?
1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

30. How often do you jog/run?
1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

31. How often do you bicycle?
1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

32. How often do you swim?
1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

33. How often do you row?
1 □ Never 2 □ Seldom 3 □ Occasionally 4 □ Frequently 5 □ Always

Questionnaire instructions: Please answer by putting an "X" in the appropriate box. You may only provide one "X" for each question. You may be uncertain how to answer, but please do your best anyways.

34. When you climb, what type of grip do you use *most*?
1 □ Pinch
2 □ Open
3 □ Crimp/Cling
4 □ Wrap

35. When you climb, what type of grip do you use *least*?
1 □ Pinch
2 □ Open
3 □ Crimp/Cling
4 □ Wrap

36. What do you expect to be able to climb today?
1 □ V0 – V3
2 □ V4 – V7
3 □ V8 – V11
4 □ V12 – V15

37. How many Pinch grip pull-ups can you do with your entire body weight and full range of motion?
1 □ 0
2 □ 1
3 □ 2-3
4 □ 4-5
5 □ ≥ 6

38. How many years have you climbed?
1 □ ≤ 1 year
2 □ 1 - 2 years
3 □ 3 - 4 years
4 □ 5 - 6 years
5 □ ≥ 7 years

39. What is your age? ________yrs

40. What is your gender?
1 □ Female 2 □ Male