1993

Anthropometric, flexibility, and strength characteristics in male competitive rock climbers

Jay R. Embree
San Jose State University

Follow this and additional works at: https://scholarworks.sjsu.edu/etd_theses

Recommended Citation

Embree, Jay R., "Anthropometric, flexibility, and strength characteristics in male competitive rock climbers" (1993). *Master's Theses*. 678.

DOI: <https://doi.org/10.31979/etd.52ag-2ebe>

https://scholarworks.sjsu.edu/etd_theses/678

This Thesis is brought to you for free and open access by the Master's Theses and Graduate Research at SJSU ScholarWorks. It has been accepted for inclusion in Master's Theses by an authorized administrator of SJSU ScholarWorks. For more information, please contact scholarworks@sjsu.edu.

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

U·M·I

University Microfilms International
A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
313/761-4700 800/521-0600

Order Number 1356461

**Anthropometric, flexibility, and strength characteristics in male
competitive rock climbers**

Embree, Jay Roger, M.A.

San Jose State University, 1993

U·M·I

300 N. Zeeb Rd.
Ann Arbor, MI 48106

Anthropometric, Flexibility, and Strength
Characteristics in Male Competitive Rock Climbers

A Thesis
presented to
the Faculty of the Department of
Human Performance
San Jose State University

In Partial Fulfillment for the degree
Master of Arts

Jay R. Embree
December 1993

APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Dr. Craig Cisar, Professor

Dr. Gail Evans, Professor

Barry Bates

APPROVED FOR THE UNIVERSITY

ABSTRACT

ANTHROPOMETRIC, FLEXIBILITY, AND STRENGTH CHARACTERISTICS OF MALE ROCK CLIMBERS.

By Jay R. Embree

Thirty-five male rock climbers age 20 to 40 years were measured on the following 11 variables: height, body mass, height/body mass ratio, arm span/height ratio, X and Y somatotype intercepts, relative fat (RF), hang time (HT), musculo-skeletal size (MS), hip adductor flexibility (AD) and hip extensor flexibility (EX). Subjects were divided into novice (N), intermediate (I), and elite (E) groups based on their performance in a climbing contest. One-way analyses of variance with Tukey post-hoc analyses showed significant differences $p \leq .05$ between N and E groups in HT, RF, AD, and EX. The E competitors were stronger, leaner, and more flexible than the novice climbers. A significant difference was also found in HT between the I and E groups. Stepwise multiple regression analysis generated a five component model (HT, RF, AD, EX, and MS), with a multiple $R = .806$ and $SEE = 5.43$. Discriminant analysis correctly categorized 80% of the subjects. These data suggest that leanness, ability to hang from holds, and hip joint flexibility are all important components in climbing performance.

Acknowledgments

To my parents, Jimmy and Patty, who regularly gave me enough rope to hang myself, yet were always there to loosen the noose. Little did they know, one day I would use that same rope to protect myself, while chasing my dreams on rock walls.

I am forever indebted to the following people: for acting as chair of my committee, Craig Cisar, Ph.D.; for sitting on my committee; Barry Bates and Gail Evans, Ph.D.; for her editing skills, Hillary Russak; for his understanding of the PEAK system, Ken Van Aalsburg; for hours of help with computer programming, Skip Masters; for help in developing and interpreting the statistical tests used in this study, Jill Fujisaki, Seth Michealson Ph.D., Susan Sacks, Ph.D., and Tony Thrall, Ph.D. I cannot thank you enough - with out your help this project could not have been completed. In addition, I would like to thank the staff of City Rock Gym of Emeryville, California who allowed me the time and space to collect data at their establishment.

Table of Contents

	page
ABSTRACT	iii
Acknowledgments	iv
Table of Contents	v
List of Tables	viii
CHAPTER I, Introduction	
Introduction	1
Background for the Study	1
Statement of the Problem	5
Approach to the Problem	5
Statement of the Hypotheses	6
Delimitations	6
Limitations	7
Definition of Terms	7
Climbing Definitions	10
CHAPTER II, Review of Literature	
Introduction	13
Review Body	13
Summary	24

Table of Contents (continued)

	page
CHAPTER III, Methods	
Introduction	25
Subjects	25
Instrumentation	26
Anthropometric Measurements	26
Measures of Flexibility	28
Bi-Dimentional Somatotype Rating	31
Measure of Strength	31
Measure of Relative Fat	32
Score	32
Analysis of Data	33
CHAPTER IV, Analysis of Data	
Introduction	35
Level of Significance	35
Analysis of Data	35
Summary of Findings	48
Discussion of Findings	49
Conclusions	58
Weaknesses	60
Recommendations for Future Research	61
References	63

Table of Contents (continued)

Appendix 1	69
Appendix 2	70
Appendix 3	73
Appendix 4	75
Appendix 5	76

List of Tables

	Page
Table 1 Watts' (1990) Data Summary	16
Table 2 Descriptive Statistics of the Subjects	37
Table 3 Descriptive Statistics of the Subjects Across Categories	38
Table 4 Zero-order Correlation Matrix of Each Variable	41
Table 5 Full-model and Stepwise Regression for the Prediction of Competition Score	43
Table 6 Rotated Discriminant Matrix for the Prediction of Climbing Score	44
Table 7 Discriminant Functions Evaluated by Centroids	46
Table 8 Category Classification Results of Multiple Discriminant Analysis	47

CHAPTER I

Introduction

This chapter has several sections: background of the study, statement of the problem, approach to the problem, research hypotheses, delimitations, limitations, and definition of terms.

Background for the Study

When one typically thinks of "climbing", thoughts of snow covered mountains, high winds, and planting a flag at the top may all come to mind. Indeed, these are the roots of climbing; yet, these thoughts are very far from what one of today's competitive (sport) climbers may think of when climbing is mentioned. To the competitive climber, climbing may mean ascending a wall of only 25 feet; however, that wall may be so severely overhung, with holds so small and far apart that the non-climber would be unable to fathom getting off the ground, much less climbing the full 25 feet. One tends to envision climbing as the melding of one and the environment - no rules. Lito Tejada-Floresin (Wilson, 1980), in his article entitled Games Climbers Play, recognized that it is just the opposite:

...Climbing is not a homogeneous sport but rather a collection of differing (though related) activities, each with its own adapts, distinctive terrain, problems and satisfactions, and perhaps most important, its own rules. ...it would be an absurdity to use a ladder to reach the top of a boulder in Fontainbleau, but to use the same ladder to bridge a crevasse in the Khumbu Icefall would be reasonable, since Everest defends itself so well that one ladder no longer tips the scales toward certain success...(Wilson, 1980, p. 19)

Competition climbing is no different than other forms of climbing; the competitive climbers have simply taken the time to put their rules on paper.

Past study of climbing has centered on the mountaineer, with issues of muscle catabolism at high altitude (Boyer & Blume, 1984) and whether psychology or physiology plays the greater role in getting to the top (Oelz, Howard, DePrampero, Hoppeier, Jenni, Buhlmann, Ferretti, Bruckner, Veicsteinas, Gussoni, & Cerretelli, 1986). To date, very little research has focused on those climbers who do not perform at high altitude.

What is known about the true competitive climber is an even smaller fraction of this meager body of knowledge.

Physiologic and anthropometric profiling of athletes has been a useful tool in many sports. These profiles have aided athletes and coaches in determining appropriate training regimes, team member selection criteria, and in predicting success (Åstrand & Kaare, 1986). Unfortunately, such profiles do not exist for the competitive climber. This forces these athletes to rely on information that has gained popularity through hearsay, rather than a scientific basis. Profiling the sport climber would ease this deficit.

Lefebvre (1980) demonstrated that reaching the top of a rock climb can generate stronger feelings of vitality, competence, and positive self-evaluation than taking part in other activities. Establishing appropriate training regimes may motivate more people to take part in climbing and, consequently, increase these positive feelings in these individuals.

Over the last decade, climbing standards have increased at an incredible pace. A much larger climbing population, the introduction of organized competition (complete with a governing body), ethical changes, and

equipment advances, which have all but eliminated the risk of serious falls have all contributed to the climbing of more difficult routes. These advances have put greater physical demands on the sport climber and, consequently, the climber must train more rigorously to keep-up with the ever increasing standards.

Because climbers are now training with much greater volume than in the past and the risk of serious falls is much lower than ever before, the likelihood of injury is now much greater from over/incorrect training than from actually falling while climbing (Bannister & Fister, 1986; Bolen, 1988; Jones, 1990). Again, profiling would aid in the design of appropriate training techniques.

There is, to this author's knowledge, no scientifically-based information regarding a profile of expected flexibility at different joints in the sport climber. However, in the analysis of a questionnaire, Jones (1990) found that 97 percent of the respondents who reported stretching before climbing also reported an overuse injury. Unfortunately, it was not deciphered as to whether or not the subjects stretched prior to being injured or only after a physician had prescribed stretching to reduce the risk of future injury/re-

injury. In addition to anthropometric profiling, it would appear that information concerning the flexibility of the sport climber would also be beneficial.

Statement of the Problem

The purpose of this study was to perform several measures in order to profile male competitive climbers. These measures included tests of anthropometry, flexibility, and strength.

Approach to the Problem

Thirty-five competitive male climbers were assessed using standard lab techniques, as well as some techniques developed specifically for this study, to determine the independent variables of body mass, height, height to body mass ratio, arm span to height ratio, relative fat, musculo-skeletal size, X and Y bi-dimensional somatotype ratings, hang time, hip extensor flexibility, and hip adductor flexibility. These data were then statistically compared to the dependent variable of the subject's scores in a recreational climbing contest.

Statement of the Hypotheses

1. There will be no difference in the body mass, height, body mass to height ratio, arm span to height ratio, hip extensor flexibility, hip adductor flexibility, relative fat, hang time, musculo-skeletal size, X somatotype intercept, or Y somatotype intercept between novice, intermediate and elite climbers.

2. None of the variables standing on their own will be correlated with climbing ability.

3. No combination of variables will have any predictive ability with regard to climbing ability.

4. No variable or combination of variables will have any predictive power with regard to the classification of climbers.

Delimitations

This study was delimited to 35 healthy male competitive climbers who took part in a recreational climbing competition at the City Rock Gym in Emeryville, California. The study was further delimited to artificial, top-roped climbing surfaces which are similar to the climbing surfaces at the City Rock Gym.

Limitations

Several factors limited this study. Because of the nature of a recreational climbing contest, contestants had the opportunity to see other climbers climb routes before they attempted the routes, thereby giving them knowledge of the route prior to their attempt (i.e., not an on-site attempt). The equipment used by the climbers (clothing, shoes, harness, chalk and chalk bag) were of the climber's personal preference - different climbers used different equipment. Also, genetic make-up, motivation level, nutritional status, training status, and pre-testing and pre-competition activity of the climbers were not controlled.

Definition of Terms

Arm Span. Arm span is the distance between the tips of the third (longest) fingers of each hand (excluding the finger nails) when both hands are extended laterally and maximally to the level of the shoulders (Lohman, Roche & Martorell, 1988).

Bi-Dimensional Somatotype Ratings. Bi-dimensional somatotype ratings are the X and Y intercepts on a somatochart. These are derived when the formula of Ross and Wilson (1973) are applied to the three component

results of the Heath-Carter somatotyping method (Heath & Carter, 1967). The X component represents linearity minus fatness and is determined by the following formula; ectomorphy minus endomorphy, while the Y component represents a measure of muscularity and is calculated using the following formula; $Y = 2 \text{ times mesomorphy minus the sum of endomorphy and ectomorphy.}$

Body Mass. Body mass is often referred to as weight or body weight and is represented by a subjects mass in kilograms (kg) as measured on a beam style scale (Lohman, Roche & Martorell, 1988).

Arm Span to Height Ratio. Arm span to height ratio is defined in this study by the following calculation: arm span to height ratio = arm span divided by height.

Fat Mass. Fat mass is the total mass in kg of adipose tissue in a subject and is determined by the following formula: fat mass = body mass minus lean body mass (Brozek, Grande, Anderson, & Keys, 1963).

Hang Time. Hang time is defined in this study as the time (to the nearest 1/10 second) a subject can hang from two "three finger pockets" on a Metolius Pure Force brand hangboard.

Heath-Carter Somatotype. The Heath-Carter somatotyping procedure is a method of characterizing the body build of a subject with regard to endomorphy (fatness of an individual), mesomorphy (the muscularity of an individual), and ectomorphy (the linearity of an individual) (Heath & Carter, 1967).

Height. Height is the distance in cm from the floor to the top of a subject's scalp, when a subject stands erect, in bare-feet, with the balls and heels of the feet on the floor (Lohman, Roche & Martorell, 1988).

Height to Body Mass Ratio. Height to body mass ratio is determined by the following formula: height to body mass ratio = height divided by body mass.

Hip Adductor Flexibility. Hip adductor flexibility is defined in this study as the number of degrees the hip abductors can abduct the extended leg from the anatomical position in-line with the frontal plane.

Hip Extensor Flexibility. Hip extensor flexibility is defined in this study as the number of degrees the hip flexors can flex the extended leg from the anatomical position anteriorly in-line with the sagittal plane.

Lean Body Mass. Lean body mass is the total mass in kg of lean tissues in a subject and is determined by the following formula: lean body mass = body mass minus fat mass (Brozek et al., 1963).

Musculo-Skeletal Size. Musculo-skeletal size is determined by the following formula: = lean body mass (Kg) divided by height (cm) (Slaughter & Lohman, 1980).

Relative Fat. Relative fat is the proportion (percent) of body mass composed of adipose tissue and is determined by the following calculation: $[(4.57/\text{body density}) - 4.142] * 100$ (Brozek et al., 1963).

Climbing Definitions

Hangboard. A hangboard is a training device similar to a pull-up-bar except there are several different holds (ranging from very small to very large) from which the climber can hang (or do pull-ups).

Intermediate Hold. An intermediate hold is a hold on a climb which is not used as a main support, but instead, as a stabilizing hold which allows the climber to get to the next hold which is large enough to allow greater support.

Lock-Off. Locking-off is a term used to describe the arm position one has in the up position of a pull-

up. This position takes much less energy to hold than any other angle created during a pull-up, and is used to allow the climber to rest or reach the next higher hold on a climb.

On-Site. On-site is the term given to a climbing attempt when the climber has not previously gained any knowledge of the route, prior to the climber's first attempt at climbing the route (i.e., no map review or discussion with others who have done the route).

Recreational Climbing Contest. A recreational climbing contest is a climbing contest in which the contestants may choose from many routes [$\approx$ 100 very short (10-50 feet) routes]. The contestant chooses eight routes to attempt to climb. The contestant may attempt each route up to three times. If a contestant is successful in climbing a route, the climber is awarded points. Each climb is rated (see Yosemite Decimal Rating System) and point values for the routes increase as the ratings of the routes increase. After attempting the eight routes, the six climbs with the highest points values are totaled. This allows a contestant to fail on one or two climbs (i.e., not climb it within three attempts) and still put together a potentially winning

score. The contestant with the highest score wins. In the case of a tie in points scored, the contestant with the fewest attempts wins.

Top-Rope. Top-rope is a climb which is protected by a rope from the top of the climb. This system is considered the most safe method of protecting a route because, when a climber falls (becomes detached from the climb), the climber is suspended by the rope and does not fall any distance at all.

Yosemite Decimal Rating System. The Yosemite decimal rating system is a numerical and alphabetical series which ranges from 5.0, 5.1, 5.2,...5.9 (read as five-zero, five-one,...five-nine) and continues 5.10a, 5.10b, 5.10c, 5.10d, 5.11a,...5.14d (read as five-ten-a, five-ten-b,...five-fourteen-d). The "five" prior to the decimal point tells the climber that ropes should be used to protect potential falls, but do not need to be used to climb the route being described. The number (and letter) after the decimal point describes the technical difficulty of the route. The higher the number, the more difficult the route (Roper, 1972).

CHAPTER II

Review of Literature

Introduction

To more fully understand this research topic, a thorough review of the literature was completed. Books, refereed journals, and popular publications were all assessed to help mold the design of this investigation. Studies attempting to profile rock climbers and similar athletes were located, including one which was directed specifically toward competitive climbers. In addition, several miscellaneous articles discussing related areas (such as the physics of climbing) were found. Each of these is discussed in detail in the body of this chapter.

Review Body

Hardy and Martindale (1982) investigated the energy expense, lactate tolerance, and electrocardiographic (EKG) response to rock climbing. Seven male subjects were divided into two groups. Beginners climbed an easy route rated 4a [a British rating equivalent to 5.6 (Darmi, 1989)] and an expert group climbed a route rated 5c [a British rating equivalent to 5.10c (Darmi, 1989)]. Lactate information was collected by taking a blood

sample from each subject's right forearm prior to the subject starting to climb, and from the left forearm immediately after the subject could no longer hold on to the climbing surface. The climbers were instructed to traverse back and forth along an artificial climbing wall as long as they could. Oxygen consumption and EKG data were then collected by pushing a cart with an oscilloscope and gas analyzers along the base of the wall as each subject traversed.

The authors found that the expert climbers did significantly ($p < .01$) more external work (i.e., traversed further) at a lower energy expense than did the beginners, even though their climbing route was of a harder grade. Mean blood lactate measures were not statistically different; however, there was a trend in which the experts did show a higher tolerance to blood lactate accumulation suggesting that the experts may have greater tolerance than novice climbers. The results of this study suggest that efficiency/skill plays a large role in how well an individual may climb. These results should, however, not be given too much weight, as the sample size was very small.

In a short article, Rock and Ice Magazine (Watts, 1990) published some anthropometric and strength data collected from male and female competitors at a World Cup Climbing Competition. These data, though not published in a refereed journal, are perhaps the closest to the subject population that was used in this study and are therefore included in this review. The means for these data are summarized in Table 1.

The subjects in this study all climbed at a level above 5.12 and represented genuinely elite climbers. Unfortunately, there were no results of statistical tests for significance included in that article. However, from an empirical perspective, it appeared that total body mass may play an important role at the elite level of sport climbing. Grip-strength is the only other value which seemed to have a large difference between the two groups, but it became identical when adjusted for body mass. This, coupled with the fact that relative fat was similar in each group, may suggest that even excess muscle may be a detriment at the elite end of the sport. For this reason, a measure of musculo-skeletal size was included in this investigation. It was also interesting to note that the

Table 1

Watts' (1990) Data Summary

Men	Semifinalist	Finalists
Number tested	21.00	7.00
Age (yr)	26.50	23.80
Years climbing	11.20	8.60
Height (in)	69.80	70.30
Body mass (lb)	146.60	137.20
Sum of 7 skin-folds (mm)	37.80	36.30
Percent body fat	4.70	4.80
Hand-arm volume (ml)	1523.20	1364.40
Grip-strength (lb)	113.70	107.10
Grip-strength/body mass ratio	.78	.78

grip-strength scores were only at about the 75th percentile when compared to norms (Montoye & Lamphiear, 1977).

In contrast to the Rock and Ice article, Russum (1989) found grip-strength to be one of the best predictors of climbing ability when this investigator measured fourteen different variables on 40 male climbers with self-reported climbing abilities ranging from 5.5 to 5.12. From these data, the author attempted to predict each climber's category of ability (beginner <5.8, intermediate 5.9-5.10d, or elite >5.11a). Russum found shoulder strength, body mass, and grip strength to account for 45.3% of the variance in climbing ability. Again, body mass appeared to play a key role. It is, however, unclear as to whether or not grip-strength is the best predictor of finger flexion strength with regard to climbing performance. Because of this ambiguity regarding grip strength, this author chose to use the number of seconds each subject could hang from two three-finger-pockets on a hangboard as a measure of strength, rather than grip strength measured by a grip dynamometer, in hopes that this method would provide a better predictor of a climbing ability.

Russum's study also identified several variables which did not reach a significant difference between different categories of climbing ability. These variables included: leg strength, arm strength, anaerobic power, anaerobic capacity, fatigue index, ventilatory threshold, maximal oxygen uptake rates, and X and Y bi-dimensional somatotype ratings.

Although neither X nor Y bi-dimensional somatotype rating were found to reach a level of statistical significance in any of the statistical tests (one-way analysis of variance, pearson product moment correlation, stepwise multiple and full-model regression analysis or discriminant analysis) in Russum's study, this author chose to include this measure in this investigation. It may have been the skew of Russum's sample (there were many more novice and intermediate climbers than elite climbers) that contributed to that study's statistical insignificance on X and Y bi-dimensional somatotypings. From an empirical view point, competitive climbers who do well appear to be very similar in body build and consequently, bi-dimensional somatotypings were included in this study.

Russum's study was put together in a very thorough manner and is perhaps, the best rock climbing profile currently available. Unfortunately, the subject pool of elite (defined, by the author, as climbing 5.11a or above) was relatively small (eight of the 40 subjects). In addition, if one were to change the definition of elite to match today's standards, the pool would have been even smaller. Another criticism of the Russum study was the use of self-reported climbing ability. Subjects either knowingly or unknowingly may have misclassified themselves. The potential of this problem was reduced in this study by having all subjects compete in a recreational climbing contest (with data taken within a two-week period either before or after the contest) and thereby, correctly classifying each subject at that point-in-time. Lastly, Russum made suggestions for future research, which included issues of: psychology, strength to mass ratios, lactic acid tolerance levels, technical skill, and flexibility.

Mace (1979) investigated physiological arousal in beginning and experienced rock climbers while repelling (a method of descending a fixed line). To accomplish this, he recorded heart rates as subjects repelled down

a wall of a 70 foot tall building. The results indicated that the beginners became very aroused (heart rate mean = 155 beats per minute), while the experienced group showed little or no increase (heart rate mean = 90 beats per minute).

This study did not actually test one's ability to rock climb, but it may have an application in this study. A recreational climbing contest employs top-rope systems to protect the participants. It has been speculated that competitors may become frightened of falling and consequently not climb at their limit. Repelling creates the same sensations as using a top-rope (i.e., hanging from a rope). Therefore, Mace's study suggested that climbers are accustomed to this feeling and should not be affected by this technique of protection.

There was previously no research regarding flexibility and the rock climber. However, other authors (Russum, 1989) have likened the rock climber's profile to that of a gymnast's and there are studies regarding flexibility profiles on this population.

Haywood, Clark, and Mayhew (1986) investigated the effects of training on strength and flexibility in

female swimmers and gymnasts age 7 to 12. Measures of strength included: arm strength with the hands at three different positions (over the head, chest level, and waist level). Flexibility was assessed via trunk rotation, ankle plantar flexion and dorsiflexion, and shoulder hyperextension and abduction.

The results indicated that the swimmers had larger waist girths and greater lean body mass; yet, the gymnasts created greater forces on all the strength measures. This, again, implies that the athlete who must support their full body mass tended to be a comparatively small and light individual. With regard to flexibility, the picture was not so clear. No significant differences were found between the two groups in shoulder flexibility measures. The gymnasts, however, possessed greater flexibility in the trunk than did the swimmers. The opposite was true with regard to ankle flexibility. It is unfortunate that measures of hip flexibility were not included in this study.

In a somewhat longitudinal study (Lufi, Porat, & Tenenbaum, 1988), 56 young male gymnasts were given a battery of tests which included: standing long jump,

pull-ups, running between lines, shoulder flexibility, sit-ups, coordination exercise, Wells test, and hip adductor flexibility. From the scores they received, the top 14% were labeled the high potential group while the lower 86% were classified as the average potential group (the subjects were not made aware of the groupings). Over the following year, each subject took part in four gymnastics meets. The researchers found that those subjects in the high potential group scored an average of 0.5 points higher for their routines than did the other group. This difference did not, however, reach statistical significance; although the author pointed out that a 0.5 point variation is quite large in a gymnastics event and therefore, has some logical relevance. Other non-refereed articles have echoed the idea that both strength and flexibility play an important role in predicting gymnastic success (Boone, 1988; Scannell & Savage, 1987).

While not specifically related to either the gymnast or the rock climber, Gebbard, Miller, and Thiebaud (1984) examined ankle flexibility in 39 children age 4 to 8 years, as they climbed ladders positioned at 90, 67, 40, 24, 14, and 0 degrees from the

horizontal position. They found that the greatest ankle flexion (dorsi and plantar) occurred at the greater angles (40 to 90 degrees). Again, because of the age of the subjects, this population was quite different than the one used in this study; yet, their results may have some interesting implications with regard to the study of competitive climbers. Since ankle mobility increased with increasing angle, ankle flexibility may be of some consequence in rock climbing.

This review of literature found some investigations (Hudson & Johnson, 1976; Walker, 1989) which had attempted to apply the laws of physics to climbing (i.e., a purely quantitative analysis of the forces involved). While these are useful theoretical devices, they do not shed much light on real world situations and consequently, provided little additional information toward the formulation of this investigation.

There was no literature found to support or refute the use of arm span to height ratio as a predictor of climbing ability. However, within the climbing community, people speak of an "ape index." The ape index is simply how long one's arm span is in relation to one's height. Therefore, it seemed reasonable to

include a measure of arm span to height ratio in a study such as this.

Summary

Investigations into rock climbing are limited at best. From what is available, it would appear that height, mass, and height to mass ratios may be important predictors of climbing ability (Russum, 1989; Watts, 1990). The body composition, musculo-skeletal size, and somatotype of the competitive climber may also be important factors (Russum, 1989). Research regarding flexibility of rock climbers did not exist prior to this study, consequently, information from other closely-related disciplines was considered. Unfortunately, no information was available (even in closely related disciplines) regarding the use of limb length measurements as possible predictors of climbing ability. However, limb length does have some hearsay history of prediction within the climbing community and was therefore included in this study.

CHAPTER III

Methods

Introduction

This section provides a detailed description of the subjects and the methods used to measure the independent variables. Also included is a description of the recreational climbing contest which was used to rank the subjects (the dependent variable).

Subjects

Subjects for this study were 35 male competitive rock climbers aged 20 to 40 years. These subjects were recruited through flyers posted at the City Rock Gym (see Appendix I) and through telephone solicitation. All subjects met the guidelines for apparently healthy subjects (American College of Sports Medicine, 1991). In addition, all subjects read and signed a consent form reviewed by the Human Subjects Institutional Review Board of San Jose State University (see Appendix II) and filled out a health summary (see Appendix III).

Instrumentation

The following data were collected (see appendix IV):

1. Anthropometric measurements
 - body mass
 - height
 - arm span
 - skin fold measurements: triceps,
sub-scapular, mid-axillary, supra-iliac,
mid-calf, and abdominal
 - flexed arm circumferences
 - diameters: elbow, and knee
2. Measures of flexibility
 - hip: adductors and extensors
3. Measure of strength
 - hang time

Data collection took between 1.0 and 1.5 hours per subject. No more than five subjects were scheduled for any one testing session.

Anthropometric Measurements

Body Mass

Body mass was determined using a standard physician's scale with current calibration

documentation. Subjects were weighed wearing only shorts, after voiding, and with dry skin and hair.

Height

Height was measured using a wall scale equipped with a Broca Plane. Subjects were instructed to stand erect with the balls and heels of the feet on the floor (Lohman, Roche & Martorell, 1988).

Arm Span

Arm span was measured by instructing the subject to extend his arms, hands, and fingers maximally at shoulder height while standing with his posterior against a wall. The distance between the tips of the third (longest) fingers of each hand was marked and the distance between the marks was measured in cm (Lohman, Roche & Martorell, 1988).

Circumferences

All circumference measurements were made using a steel tape with a Gullick handle. Flexed arm circumference was determined at maximal girth at mid-arm with elbow flexed and muscle contracted (Behnke & Wilmore, 1974).

Diameters

All diameter measurements were made using a broad-blade metal anthropometer. Elbow diameter was determined by measuring the distance between the condyles of the humerus, with the elbow flexed and the hand supinated (Behnke & Wilmore, 1974). Knee diameter was determined by measuring the distance between tibial condyles, with the knee flexed at 90 degrees (Behnke & Wilmore, 1974).

Skinfolds

Skinfold measurements were taken with a Harpenden Caliper (10 g/mm²). Measurements were made repeatedly until two measurements at each site were within 0.50 mm of one another. Measurements were taken at the following sites: triceps, subscapular, mid-axillary, supra-iliac, mid-calf, and abdomen. All measurements were taken using the methods described by Behnke and Wilmore (1974).

Measures of Flexibility

In attempting to evaluate spinal flexion and rotational flexibility, Netzer (1992) employed the PEAK Three Dimensional Motion Measurement System. This system allows the investigator to digitize previously

videotaped subjects and, via the PEAK system, analyze the joint(s) in question. This procedure was conducted as follows: bony landmarks were marked (in an example evaluating hip extensors: greater trochanter and lateral condyle of the femur, and the lateral malleolus); the subject was then instructed to move the body part(s) being evaluated. The movement was videotaped with a standard VHS camcorder using standard half-inch video tape and recorded at a film speed equivalent of 60 frames per second. Later, these data were analyzed with the PEAK system and range of motion was determined. This system eliminated the subjectivity of using a goniometer.

Since Netzer did not measure the same joints as were in question in this study and the author had only little prior experience in digitizing, the author first sought tutoring by an individual who had used the system extensively, and then videotaped (per methods described below) 10 volunteers and analyzed their results. These results were then compared to measurements taken with a goniometer. Pearson product-moment correlations coefficients for hip adductor, hip flexor, hip extensor, and ankle plantar and dorsiflexion range of motions

ranged from $r=.81$ to $r=.92$, demonstrating high validity (Safrit,1986). In addition, to demonstrate reliability, the author re-digitized these videotapes and calculated Pearson product-moment correlations between the original numbers and the re-digitized values. The reliability coefficients were high ranging from $r=.88$ to $r=.95$ (Safrit,1986) for the range of motions used in this study.

Hip adductor flexibility was measured by positioning the subject lying on his side with his posterior against a wall; the anterior aspects of the greater trochanter, patella, and talus were marked. The subject was then instructed to abduct the up-side leg (leg extended) as far as possible (visual cues were included in the instructions, as many subjects were not familiar with the term "abduct"). This movement was videotaped with the camera set level and perpendicular to the subject at a distance that allowed the subject to fill the frame. Measures of both right and left hip adductor flexibility were taken and their mean was considered the measured value.

Hip extensor flexibility was measured by positioning the subject supine on the floor with the

greater trochanter and lateral aspect of the malleolus marked. The subject was then instructed to flex the hip (leg extended with toes pointed) as far as possible (visual cues were included in the instructions, as many subjects were not familiar with the term "hip flexion"). This movement was videotaped with the camera set level and perpendicular to the subject at a distance that allowed the subject to fill the frame. Measures of both right and left hip extensor flexibility were taken and their mean was considered the measured value.

Bi-Dimensional Somatotype Ratings

The Heath-Carter (Heath and Carter, 1967) method of somatotyping was employed to determine the predominance of endomorphy, mesomorphy, and ectomorphy. Once these entities had been defined, X and Y bi-dimensional somatotype ratings were derived using the following formulas of Ross and Wilson (1973): $X = \text{ectomorphy} - \text{endomorphy}$ and $Y = 2 \times \text{mesomorphy} - (\text{endomorphy} + \text{ectomorphy})$.

Measure of Strength

Hang Time

Several training devices were available for increasing contact strength (ability to hang on to

holds). Using such a device, the subjects were instructed to hang from two "three finger pockets" on a Metolius Pure Force brand hangboard. The "three finger pockets" were chosen because they are a relatively large hold (one all subjects were able to hang from) and incorporate an "open hand grip". In addition, the "open hand grip" carried less risk of injury than other grip forms (Metolius Training Guide 1988, 1988) and therefore, reduced the risk of injury to the subject. The total time, measured to the nearest one tenth of a second, the subject was able to hang served as the measured value.

Measure of Relative Fat

Body density was derived via the formula of Forsyth and Sinning (1973): $1.10647 - (0.00077 * \text{triceps}) - (0.00162 * \text{scapular}) - (.00144 * \text{abdominal}) + (0.00071 * \text{mid-axillary})$. This formula was selected because it fared well in a cross-validation study (Cisar, Housh, Johnson, Thorland, & Hughes, 1989) using similar subjects (male runners) in this study.

Score

Each subject took part in the "1992 City Rock Pumpkin Pump Recreational Climbing Contest" (see

Appendix V). Each subject's score was then calculated using the following formula: competition score divided by number of routes completed. Subjects were categorized as novice, score less than 50 (climbing at or below 5.10d); intermediate, score greater than or equal to 50 but less than 60 (climbing between 5.11a and 5.11d); or elite, score greater than 60 (climbing at 5.12a or higher).

Analysis of Data

Mean, standard deviation, minimum value, and maximum value for each variable were used to describe the subjects. One-way analyses of variance and Tukey post hoc tests were used to compare the novice, intermediate, and elite climbers on the independent variables measured. A zero-order correlation matrix was produced to evaluate each independent variable as a separate predictor of climbing ability as well as the intercorrelations between the independent and dependent variables. Full-model and stepwise multiple regression were employed to create a regression equation for the prediction of climbing ability from the independent variables measured. Thirty-five subjects gave the study a ratio of slightly over three subjects per variable

being measured. According to the guidelines set in Jackson's (1984) paper regarding this type of analysis, this ratio is appropriate for multiple regression analysis. Multiple discriminant analysis was performed in an attempt to evaluate the independent variables ability to categorize the climbers as to novice, intermediate, or elite climbing ability. The SAS software package (version 6.02) was used in the analysis of these data.

CHAPTER IV

Analysis of Data

Introduction

This chapter includes details of the statistical tests performed on these data, summary of the findings, and a discussion of the findings and how they relate to previous investigations.

Level of Significance

Tests in this investigation were considered statistically significant when the probability (p) was less than .05.

Analysis of Data

The author had originally intended to have 13 variables and 40 subjects in this study. However, in the end only 35 subjects were recruited. In order to maintain an appropriate subject to variable ratio (Jackson, 1984), the author was forced to reduce the number of independent variables from 13 to 11. Person product-moment correlations were calculated between the subjects climbing score and each of the original 13 independent variables. The 11 independent variables with the highest correlation coefficients were selected for inclusion in this investigation.

Table 2 provides descriptive statistics for all the dependent and the independent variables in this study (age has also been included). The table shows the wide ranges in the subjects' anthropometric measurements as well as their ability to perform different tests which made-up the independent variables in this investigation.

Table 3 compares the subjects categorized by climbing ability. The significant results of one-way analysis of variance and Tukey post-hoc analyses are also noted. While no variable showed a significant difference between all categories, hang time was significantly different between the novice and elite categories ($p \leq .05$), and also between intermediate and elite categories ($p \leq .05$). These differences in both cases showed lower hang time scores for the novice climbers when compared to the intermediate and elite climbers. Other statistically significant findings of this analysis were as follows: relative fat was lower ($p \leq .05$) in the elite climbers when compared to the novice climbers and hip adductor and extensor flexibilities were both significantly greater ($p \leq .05$) in elite climbers when compared to the novices. Although there were no other significant differences between groups,

Table 2

Descriptive Statistics of the Subjects

<u>n</u> = 35	Mean	Minimum	Maximum	SD
Age (yr)	30.30	20.40	39.90	3.43
Height (cm)	177.00	160.70	193.00	8.13
Body mass (kg)	73.15	53.30	141.52	14.95
Height/body mass (cm/kg)	2.48	1.27	3.05	0.32
Arm span/height (cm/cm)	1.08	0.95	1.08	0.03
Relative fat (%)	12.78	6.30	41.69	6.76
Musculo-skeletal size (kg/cm)	0.38	0.29	0.76	0.08
X somatotype intercept	0.65	-9.65	3.63	2.28
Y somatotype intercept	3.50	-2.94	12.42	2.99
Adductor flexibility (deg)	55.88	30.90	84.85	12.11
Extensor flexibility (deg)	79.25	57.55	99.90	11.49
Hang time (sec)	64.29	1.80	131.00	27.09

Table 3

Descriptive Statistics of the Subjects Across Categories

Variables	Groups		
	Novice	Intermediate	Elite
<u>n</u>	11	13	11
Height (cm)	177.90 $\pm$ 2.750	177.41 $\pm$ 2.340	175.67 $\pm$ 2.190
Body mass (kg)	79.39 $\pm$ 7.170	72.11 $\pm$ 2.320	68.15 $\pm$ 1.850
Height/body mass (cm/kg)	2.36 $\pm$ 0.140	2.48 $\pm$ 0.070	2.59 $\pm$ 0.040
Arm span/height (cm/cm)	1.02 $\pm$ 0.007	1.01 $\pm$ 0.008	1.03 $\pm$ 0.010
X somatotype intercept	-0.40 $\pm$ 0.990	0.68 $\pm$ 0.500	1.68 $\pm$ 0.240
Y somatotype intercept	3.84 $\pm$ 0.990	3.33 $\pm$ 0.960	3.35 $\pm$ 0.670
Relative fat (%)*	17.21 $\pm$ 2.850	12.45 $\pm$ 1.260	8.74 $\pm$ 0.400

Values represent $\bar{M} \pm \text{SEM}$.

* One-way analysis of variance significant at $p \leq .05$ and Tukey post-hoc difference between novice and elite categories.

Note: One-way analysis of variance for relative fat, $F < .0058$, Tukey post-hoc difference between novice and elite means = 6.024.

Table 3 (continued)

Descriptive Statistics of the Subjects Across Categories

Variables	Groups		
	Novice	Intermediate	Elite
<u>n</u>	11	13	11
Musculo-skeletal size (kg/cm)	0.41 $\pm$ 0.038	0.37 $\pm$ 0.012	0.34 $\pm$ 0.006
Hang time (sec)* **	50.30 $\pm$ 8.150	54.94 $\pm$ 4.650	9.32 $\pm$ 6.100
Adductor flexibility (deg)	50.35 $\pm$ 3.430	54.83 $\pm$ 2.900	62.66 $\pm$ 3.720
Extensor flexibility (deg)*	73.37 $\pm$ 2.770	77.85 $\pm$ 2.810	86.79 $\pm$ 3.550

Values represent $\bar{M} \pm \text{SEM}$.

* One-way analysis of variance significant at $p \leq .05$ and Tukey post-hoc difference between novice and elite categories.

** One-way analysis of variance significant at $p \leq .05$ and Tukey post-hoc difference between intermediate and elite categories.

Note: One-way analysis of variance for hang time $F = .0002$, Tukey post-hoc difference between novice and elite means = 34.168, Tukey post-hoc difference between intermediate and elite means = 34.380. One-way analysis of variance for extensor flexibility $F = .0211$, Tukey post-hoc difference between novice and elite means = 13.266.

there were several measures which appeared to have logical trends. Body mass, relative fat, and musculo-skeletal size means were lowest in the elite climbers and highest in the novice climbers, while the height to body mass ratio was highest in the elite group and lowest in the novice group. Height, height/arm span ratio, and Y somatotype rating had no clear trends.

A zero-order correlation matrix is provided in table 4. Variables which were significantly related to climbing score included body mass ($r = .44$), height to body mass ratio ($r = .43$), X somatotype rating ($r = .51$), relative fat ($r = .64$), musculo-skeletal size ($r = .52$), hang time ($r = .68$), hip adductor flexibility ($r = .43$), and hip extensor flexibility ($r = .43$). Also noted was the very poor inter-correlations between flexibility measures and other independent variables, yet significant correlations when compared to climbing score. This suggests these measures accounted for variance for which the other variables were not accounting. Arm span to height ratio similarly had poor inter-correlations with other independent variables as well as poor predictive power with regard to competition score. Consequently, it was of little help in this

Table 4

Zero-order Correlation Matrix of each Variable (n=35)

	Score	Ht	BM	Ht/BM	Arm/HT	X	Y	RF	MSS	Hang	AD
Height (HT)	-.12										
Body mass (BM)	-.44*	.52*									
Height/body mass ratio (HT/BM)	.43*	-.46*	-.96*								
Arm span/height ratio (Arm/HT)	-.03	.17	.21	-.24							
X somatotype intercept (X)	.51*	.17	-.72*	.75*	-.12						
Y somatotype intercept (Y)	-.18	-.37*	.47*	-.58*	-.03	-.77*					
Relative Fat (RF)	-.64*	.03	.72*	-.69	.13	-.89*	.48*				
Musculo-skeletal size (MSS)	-.52*	.29	.96*	-.94*	.19	-.88*	.61*	.85*			
Hang time (Hang)	.68*	-.31	-.61	.64	-.11	.54*	-.25	-.60*	-.63*		
Hip adductor flaxibility (AD)	.43*	-.06	-.07	.01	-.11	.10	.17	-.20	-.09	.25	
Hip extensor flexibility (EX)	.43*	-.07	-.07	-.01	.18	.05	.18	-.15	-.07	.36*	.37*

* Significant at $p \leq .05$.

investigation attempting to develop a model to predict climbing ability.

Table 5 summarizes the results of full-model and stepwise multiple regression analyses. The full-model multiple regression analysis resulted in a multiple $R = .815$, standard error of estimate (SEE) = 5.31 accounting for 66 percent of the variance in climbing ability. The stepwise multiple regression analysis developed a five component model using hang time, relative fat, hip adductor flexibility, hip extensor flexibility, and musculo-skeletal size to predict climbing ability. This model did almost as well as full-model multiple regression analysis with a multiple $R = .806$ and $SEE = 5.43$ and accounted for 65% of the variance in climbing ability. The formula for predicting climbing score was:
$$\text{Score} = 15.9825 + (0.19255)\text{hang time} - (1.01288)\text{relative fat} + (0.21286)\text{adductor flexibility} + (0.17920)\text{extensor flexibility} + (34.144)\text{musculo-skeletal size}.$$

Table 6 shows the rotated discriminant function coefficients for each discriminant function. These functions represent the relative importance of each of the predictor variables to the discriminant function. Function 1 included height to weight ratio, arm-span to

Table 5

Full-model and Stepwise Multiple Regression for the Prediction of Competition Score

<u>Variable</u>	<u>Full-model*</u>	<u>Stepwise**</u>	
	Regression Coefficient	R ²	F
Hang time (sec)	0.2030	0.464	28.608**
Relative fat (%)	-1.6293	0.550	6.095**
Adductor flexibility (deg)	0.2314	0.616	5.287**
Extensor flexibility (deg)	0.1933	0.640	2.028**
Musculo-skeletal size (cm/kg)	209.1700	0.650	0.833**
X somatotype intercept	0.3444	0.654	0.0021
Y somatotype intercept	-1.5521	0.662	0.7679
Height (cm)	-0.3023	0.663	0.0226
Body mass (kg)	-0.6844	0.663	0.1017
Height/body mass (cm/kg)	-13.0480	0.663	0.0735
Arm span/height (cm/cm)	-6.7290	0.664	0.0068
(Constant)	15.9285		

* $p \leq .05$; $R = .815$, SEE = 5.31

** $p \leq .05$; $R = .806$, SEE = 5.43

Note: Score = 15.9285 + (0.19255)hang time - (1.01288)relative fat + (0.21286)adductor flexibility + (0.17920)extensor flexibility + (34.144)musculo-skeletal size.

Table 6

Rotated Discriminant Matrix for the Prediction of
Climbing Score

Variable	Function 1	Function 2
Height/body mass (cm/kg)	-4.952*	-0.663
Arm span/height (cm/cm)	0.312*	0.226
Y somatotype intercept	-1.285*	-0.902
Hang time (sec)	0.967*	0.228
Extensor flexibility (deg)	0.330*	-0.254
Height (cm)	-4.697	-6.805**
Body mass (kg)	2.185	8.184**
X somatotype intercept	3.024	3.889**
Relative fat (%)	1.074	2.684**
Musculo-skeletal size (cm/kg)	-3.106	-3.507**
Adductor flexibility (deg)	0.189	-0.278**

* Denotes discrimination function, function 1, with which predictor variable was most highly related.

** Denotes discrimination function, function 2, with which predictor variable was most highly related.

height ratio, Y somatotype intercept, hang time, and hip extensor flexibility and accounted for 69.3% of the variance between groups. The second function was comprised of height, body mass, X somatotype intercept, relative fat, musculo-skeletal size, and hip adductor flexibility and accounted for 28.4% of the variance between groups.

Table 7 compares functions 1 and 2 by centroids (means). Function 1 differentiated between intermediate and elite climbers best (-1.037 vs. 2.072), while function 2 discriminated best between novice and intermediate climbers (0.845 vs. -0.628).

Results of the classification of subjects from the multiple discriminant analysis are presented in table 8. This analysis correctly classified 80% of the climbers as novice, intermediate, and elite. The model correctly categorized 64 percent of the novice climbers, 77 percent of the intermediates, and 100 percent of the elite climbers. This analysis suggested that while a novice may have many of the physical attributes (i.e., strength, flexibility) needed to compete at a high level, there was something not measured in this study which would have more accurately differentiated between

Table 7

Discriminant Functions Evaluated by Centroids

Group	Function 1	Function 2
Novice	-0.932	0.845
Intermediate	-1.037	-0.628
Elite	2.072	-0.026

Table 8

Category Classification Results of Multiple Discriminant Analysis

Actual Cat.	n	Predicted Category Membership			Total
		Novice	Int.	Elite	
Novice	11	7 (63.64%)	1 (9.09%)	3 (27.27%)	11
Intermediate	13	1 (7.69%)	10 (76.92%)	2 (15.38%)	13
Elite	11	0 (0.0%)	0 (0.0%)	11 (100.0%)	11
Totals		8 (22.86%)	11 (31.43%)	16 (45.71%)	35

Note. Multiple Discriminant Analysis resulted in 80.0% correct classification of subjects.

the climbing categories. Also clear from this analysis is that no one climbed at a high level without possessing certain physical attributes such as low body mass, musculo-skeletal size, and relative fat.

Summary of Findings

One-way analyses of variance with Tukey post-hoc analyses for these data indicated statistically significant differences ($p \leq .05$) between novice and elite groups in relative fat, hang time, hip adductor flexibility, and hip extensor flexibility. The elite climbers scored longer hang times, lower relative fat, and greater hip extensor flexibility, and hip adductor flexibility than the novice climbers. In addition, there was a significant difference ($p \leq .05$) between intermediate and elite climbers when compared for hang time, with the elite climbers scoring longer hang times than the intermediate group. Pearson product-moment correlations revealed eight of the 11 independent variables were significantly related to climbing score. Variables which were significantly related included; body mass, height to weight ratio, X somatotype intercept, relative fat, musculo-skeletal size, hang time, hip adductor flexibility, and hip extensor

flexibility. Full-model multiple regression analysis resulted in a multiple $R = .806$ and $SEE = 5.31$ which accounted for 66% of the variance associated with climbing ability. Stepwise multiple regression analysis selected a five component model which accounted for 65% of the variance and had an $R = .815$ and $SEE = 5.43$. The significant contributors were hang time, relative fat, hip adductor flexibility, hip extensor flexibility, and musculo-skeletal size. Multiple discriminant analysis correctly categorized 64% of novice climbers, 77% of the intermediate climbers, and 100% of the elite climbers. In total the multiple discriminant analysis had an 80% accuracy rate in the classification of climbers. Multiple discriminant analysis also described two functions. Function 1 accounted for 69.3% of the variance between groups while function 2 accounted for 28.4%. When these functions were analyzed by centroids, function 1 discriminated between intermediate and elite climbers best, while function 2 best discriminated between novice and intermediate climbers.

Discussion of Findings

The main objective of this study was to describe characteristics common to male competitive climbers.

These data, for the most part, helped to solidify concepts expressed in other descriptive studies; however, there was also some ambiguity (contradiction in some cases) of ideas thought to be common knowledge in the climbing community. In addition to confirming or refuting the findings of other studies, this investigation also considered variables which had not previously been used in descriptive studies of climbing.

Measures related to body size, composition, and build (relative fat, height to body mass ratio, X and Y somatotype intercepts, body mass, and grip strength) have previously been associated with climbing performance (Russum, 1989; Watts, 1990). This study agrees with these previous findings. In this investigation there were six variables which were related to body size, composition, and build. They included body mass, height to body mass ratio, X and Y somatotype intercepts, relative fat, and musculo-skeletal size. With the exception of Y somatotype intercept, each of these variables was significantly related to climbing score. Also two of these variables (relative fat and musculo-skeletal size) were selected

as components in the stepwise multiple regression model predicting climbing performance.

In all but one case regarding variables related to body size, composition, and build, the lower the measurement the better the performance. The exception to this general observation was the Y somatotype intercept which was stable across all categories of climbing ability. The concept that the lower one's body mass is the better the performance is not new. Watts' (1990) data reported finalists at a World Cup Climbing Contest had a lower body mass than semi-finalists, even though relative fat was similar in both groups. This suggests a smaller musculo-skeletal size in better climbers, which was also observed in this investigation. While musculo-skeletal size mean differences were not significantly different from group to group, there was a trend toward lower musculo-skeletal size with increasing climbing ability (novice = 41 cm/kg, intermediate = .37cm/kg, and elite = .34cm/kg; mean).

There is, however, some ambiguity regarding how much muscle is appropriate. In this study, mean Y somatotype intercepts (a measure of muscularity) in the three groups were similar (novice = 3.84, intermediate =

3.33, elite = 3.35), inferring there was no difference in muscularity across categories of climbing ability. These data, however, conflict with Russum (1989), who reported elite climbers to have a higher Y intercept than climbers with a lesser ability. This ambiguity may be due to the manner in which groups were categorized in these studies. Russum labeled 5.10a - 5.10d as intermediate. In this study, these ratings were still within the novice category.

The picture may become a bit clearer when characteristics of linearity minus fatness are considered. While Y intercepts were similar in all groups, X intercept, (a measure of linearity minus fatness) were not similar. Climbers tended to be more ectomorphic with increasing climbing ability (novice = -.40, intermediate = 0.68, and elite = 1.68; mean). However, these mean differences were not statistically significant. Similarly, height to body mass ratio increased with increasing climbing ability (novice = 2.36cm/kg, intermediate = 2.48cm/kg, and elite = 2.59cm/kg; mean), again, suggesting that the linearity may be a factor underlying climbing ability.

Within the climbing community, there has been debate as to whether height facilitates or hinders climbing. Those who believe it is a hinderance believe the taller climber must carry more body mass up the wall, and because of the climber's size (comparatively large), the holds are proportionally smaller than they would be to a smaller climber. For example, a small climber may be able to get three fingers onto a hold while a large climber may only be able to fit two fingers on that same hold. Those who believe height is an advantage believe the taller climber can reach holds that the smaller climber cannot reach. Past studies have shed little light on this debate. Russum (1989) saw no difference in body height between groups of novice, intermediate, and elite climbers; and, similarly, there were no significant differences between the body height of the groups of the subjects in this study. Yet another concern is that in this study, artificial climbing surfaces were used to establish climbing ability among subjects. A common complaint of such surfaces is that they have few intermediate holds; this forces people to have to reach to the next main

hold on the course. Hence, this type of surface appears to benefit the taller climber.

The arm span to height ratio ("ape index") has not previously been used in other studies and therefore, could not be compared with the results of this investigation. This study, however, showed no predictive power for the arm span to height ratio. Means for this variable were, in fact, extremely close between groups with less than two percent separating high and low means (novice = 1.02, intermediate = 1.01, elite = 1.03; mean).

From these data and past studies an anthropometric pattern does emerge. Height of an individual appears to be relatively unimportant, at least when climbing on artificial surfaces. Important measures are relative body fat, body somatotype, and musculo-skeletal size of an individual. The person who has a low relative fat, a high ectomorphic somatotype rating, and possesses a small musculo-skeletal size is probably better suited from an anthropometric perspective, to climb than those of other anthropometric characteristics.

Grip strength is a variable which has been controversial in the findings reported by previous

studies (Russum, 1989; Watts, 1990). Russum (1989) found grip strength to be the third best predictor of climbing ability (shoulder strength and body mass being first and second) accounting for 11.5% of the variance in climbing ability. Watts (1990), working with only elite climbers, reported lower grip strength in finalists, although no difference between finalists and semi-finalists existed when grip strength was adjusted for body mass. In both Russum's (1989) and Watts' (1990) studies, grip strength in climbers were at about the 75th percentile for men of similar ages (Montoye & Lamphiear, 1977). In this study, hang time was used to more directly measure the climbers' ability to use their grip strength effectively. In addition, hang time automatically adjusted for body mass as each climber had to support himself from the holds on the hangboard. This method proved to be very effective in predicting climbing ability. This measure alone accounted for 46.6% of the variance in climbing ability. In addition, significant mean differences were observed in this variable between the novice and elite groups (50.3 seconds compared to 89.3 seconds; mean) as well as

between the intermediate and elite groups (54.8 seconds compared to 89.3 seconds; mean).

Flexibility was another area which previously had not been assessed with regard to climbing ability. Two flexibility measures (hip adductor flexibility and hip extensor flexibility) were included in this investigation. Both of these measures were contributors to the formula for predicting climbing ability that was developed through stepwise multiple regression analysis. In addition, while neither was significantly different between the groups of subjects categorized according to climbing ability, both measures exhibited a general trend when group means were reviewed (hip adductor flexibility: novice = 50.4 degrees, intermediate = 54.8 degrees, and elite = 62.7 degrees mean; and hip extensor flexibility: novice = 73.4 degrees mean, intermediate = 77.9 degrees, and elite = 86.8 degrees mean). As flexibility increased, so did climbing ability. While there were no other climbing studies which looked at flexibility, the concept of greater flexibility relating to better performance has been reported in studies from the similar discipline of gymnastics (Boone, 1988; Lufi, et al. 1988; Scannell & Savage, 1987).

The category classification results of the multiple discriminant analysis added an interesting point to this discussion. The analysis categorized 46% of the subjects as elite whereas the actual percentage was 31%. Three of the novice climbers were categorized as elite. This probably occurred because the subjects had the physical attributes of an elite climber, yet were still novices because of a lack of experience and/or skill. However, there was no mis-classification of elite climbers. These results suggest a person may have the physical attributes of an elite climber yet still not climb at an elite level. However, the converse (a person may not have the physical attributes, but possesses the skill and experience required to climb at an elite level) does not appear to be true. It is very difficult to reach the elite level without the appropriate physical attributes (low relative fat, high ectomorphic body somatotype rating, and small musculo-skeletal size). However, there are other variables such as skill and experience, which were not measured in this study. These unaccounted for variables may improve the prediction of climbing ability success at the elite level.

In addition, while the category classification portion of this analysis was an excellent predictor of elite ability, the rotated discriminant functions when compared by centroids broke out the intermediate climbers best. Function 1 best discriminated between intermediate and elite climbers, while function 2 best discriminated between the novice and intermediate climbers. However, these results suggest that with the variables used in this study one may be able to discriminate between novice, intermediate, and elite climbers with at least some accuracy.

Conclusions

Within the limits of this study the following conclusions are made:

(1) There were significant differences between groups of subjects categorized according to climbing ability in hang time (elite vs novice groups and elite vs intermediate groups), relative fat (elite vs novice groups), hip adductor flexibility (elite vs novice groups), and hip extensor flexibility (elite vs novice groups). There were no significant differences between groups in height, body mass, height to body mass ratio,

arm span to height ratio, X and Y somatotype intercepts, or musculo-skeletal size.

(2) Body mass, height to body mass ratio, X somatotype intercept, relative fat, musculo-skeletal size, hang time, hip adductor flexibility, and hip extensor flexibility were significantly correlated to climbing ability. Height, arm span to height ratio, and Y somatotype intercept were not significantly correlated to climbing ability.

(3) Stepwise multiple regression analysis identified five significant variables (hang time, relative fat, hip adductor flexibility, hip extensor flexibility, and musculo-skeletal size) which accounted for 65% of the variability in climbing ability. Full-model regression accounted for only slightly more (66.4%) of the variance in climbing ability.

(4) Multiple discriminant analysis correctly categorized 63.6% of the novice climbers, 76.9% of the intermediates, and 100% of the elite climbers. This represented 80% correct categorization of all the subjects in the study. In addition, discriminant analysis described two functions; function 1 was comprised of height to weight ratio, arm span to height

ratio, Y somatotype intercept, hang time, and hip extensor flexibility and accounted for 69.3% of the variance in climbing ability. Function 2 included height, body mass, X somatotype intercept, relative fat, musculo-skeletal size, and hip adductor flexibility and accounted for 28.4% of the variance in climbing ability.

Weaknesses

The competition used to establish climbing ability of the subjects had several properties which may have skewed the classification of the subjects. Although there were over 100 routes from which to choose, subjects selected only eight routes to climb. If a competitor watched closely he could determine which routes were easy for their rating and take advantage of this knowledge. It would have been much better if each subject would have climbed the same routes.

While the purpose of this study is to assess attributes which may affect rock climbing, climbing ability was determined in a gym climbing on resin walls with holds made of wood, plastic, and rock. True rock climbing (i.e., climbing outside on natural rock walls) is different than climbing in a gym - to what degree, we do not know. Many variables showed strong trends toward

mean differences between groups, yet did not reach statistical significance. A larger subject pool may have helped to more clearly decipher as to whether there were, in fact, significant differences in these means.

Recommendations for Future Research

(1) Descriptive studies of the future should include some measure of experience or technical skill such as the number of years subjects have climbed.

(2) Future studies should focus on women climbers. With the advent of climbing gyms, recruitment of subjects is easier than ever before. This avenue should be pursued.

(3) Studies that wish to use flexibility measures should consider hip internal rotator flexibility ("turn out") as this may play an important role in keeping body mass over the holds on which one is standing. Also there is some evidence (Gebbard, et al., 1984) that ankle flexibility may play a role in climbing performance.

(4) Future studies should attempt to break-out what attributes predict success in what type of climbing and the medium being climbed (i.e., slab, crack, steep face, volcanic rock, granite, and limestone).

(5) Attempts should be made at correlating artificial "gym" climbing to real world climbing.

(6) Climbing strength should be evaluated more in depth. Do the abilities of different subjects to hang on to different holds (pockets, jams, thin edges, slopers, etc.) correlate with performance? Does the length of time a climber can hang-on-to different types of holds predict performance? Does the ability to lock-off on a given hold predict performance?

References

- American College of Sports Medicine. (1991). Guidelines for exercise testing and prescription (4th ed.). Philadelphia: Lea & Febiger.
- Åstrand, P. O., & Rodahl, K. (1986). Textbook of work physiology: physiological basis of exercise. New York: McGraw-Hill.
- Bannister, P. & Fister, P. (1986). Upper limb injuries associated with rock climbing. British Journal of Sports Medicine, 20 (2), 55.
- Behnke, A. R., & Wilmore J. H. (1974). Evaluation and regulation of body build and composition. Englewood Cliffs, N. J.: Prentice Hall.
- Bolen, S. R. (1988). Soft tissue injury in extreme rock climbers. British Journal of Sports Medicine, 22 (4), 145-147.
- Boyer, S. J., & Blume, F. D. (1984). Weight loss and changes in body composition at high altitude. Journal of Applied Physiology, 58, 1580-1585.
- Boone, T. (1988, January). Predicting outstanding gymnastic ability. Coaching Clinic, pp. 7-8.

- Brozek, J. F., Grande, J. T., Anderson, J., & Keys, A. (1963). Densiometric analysis of body composition: revision of some quantitative assumptions. Annals of the New York Academy of Science, 110, 113-1140.
- Cisar, C. J., Housh, T. J., Johnson, G. O., Thorland, W. G., Hughes, R. A. (1989). Validity of anthropometric equations for the determination of changes in body composition in adult males during training. The Journal of Sports Medicine and Physical Fitness, 29 (2), 141-148.
- Darmi, P. (1989). The sport climbing championships competitors' guide: no publisher listed.
- Gebbard, C., Miller, G., & Thiebaud, R. (1984). Ladder angle and ankle flexion while climbing. Perceptual and Motor Skills, 59, 893-894.
- Hardy, L., & Martindale, K. (1982). Some physiological parameters in rock-climbing. Physical Education Review, 5 (1), 41-44.

- Haywood, K. M., Clark, B. A., & Mayhew, J. L. (1986). Differential effects of age-group gymnastics and swimming on body composition, strength, and flexibility. Journal of Sports Medicine, 26, 416-420.
- Heath, B. H., & Carter J. E. L., (1967). A modified somatotype method. American Journal of Physiological Anthropology, 24, 87 - 99.
- Hudson, R. R., & Johnson, W. (1976). Elementary rock climbing mechanics. International Journal of Mechanical Engineering Education. 4, 357-367.
- Jackson, A. S. (1984). Research design and analysis of data procedures for predicting body density. Medicine and Science in Sport and Exercise, 16 (6), 616-620.
- Jones, D. (1990, March/April). Injury survey report. Rock and Ice, pp. 52-54.
- Lefebvre, L. M. (1980). Somato-psychological experiences during rock-climbing. International Journal of Sports Psychology, 11 (3), 153-164.

- Lohman, T. G., Roche, A. F., and Martorell, R. (Ed.).
 (1988). Anthropometric standardization reference manual Champaign, Illinois: Human Kinetics Books.
- Lufi, D., Porat, J., & Tenenbaum, G. (1988, February).
 Physical predictors for competitive male gymnasts.
International Gymnast, pp 38.
- Mace, R. (1979). Physiological arousal in climbers.
Physical Education Review, 2 (2), 141-149.
- Metolius training guide 1988, (1988). Metolius
 Mountain Products: Bend, Oregon.
- Montoye, H. J., & Lamphiear, D. E. (1977). Grip and arm
 strength in males and females, age 10 to 69. The
 Research Quarterly, 48, 109-120.
- Netzer, O. (1992). Effects of age and gender on
 functional rotational and lateral flexion of the
 back and neck. Unpublished master's thesis, San
 Jose State University, San Jose, California.
- Oelz, O., Howard, H., DePrampo, P. E., Hoppeler, H.,
 Claassen, H., Jenni, R., Buhlmann, A., Ferretti,
 G., Bruckner, J., Veicsteinas, A., Gussoni, M., &
 Cerretelli, P. (1986) Physiological profile of
 world-class high-altitude climbers. Journal of
 Applied Physiology, 60, 1734-1742.

- Roper, S. (1972). A Sierra Club totebook climber's guide to Yosemite Valley. San Francisco: Sierra Club Books.
- Ross, W., Wilson, B., (1973). A somatotype dispersion index. Research Quarterly, 44 (3), 372-374.
- Russum, W. (1989). Physiological determinants of rock climbing ability. Unpublished master's thesis, San Jose State University, San Jose, California.
- Safrit, M. J., (1986). Measurement in physical education and exercise science. St. Louis: Times Mirror/Mosby Collage Printing.
- SAS Institute Inc. (1987). SAS/STAT guide for personal computers, version 6 edition. Cary, NC: SAS Institute Inc.
- Scannell, D., & Savage, P. (1987, April). Strength and flexibility: why they rely on one another. International Gymnast, pp. 41.
- Slaughter, M. H., Lohman, T. G. (1980). An objective method for measurement of musculo-skeletal size to characterize body physique with application to the athletic population. Medicine and Science in Sport and Exercise, 12 (3), 170-174.

- Walker, J. (1989, June). The mechanics of rock climbing, or the ultimate physics exam. Scientific American, pp. 118-121.
- Watts, P. (1990, July/August). Sport science at Snowbird. Rock and Ice, pp. 14-15.
- Wilson, K. (Ed). (1980). Games climbers play: a collection of mountaineering writing. San Francisco: Sierra Club Books.

Appendix I

SCIENCE AND CLIMBING COLLIDE AT CITY ROCK'S PUMPKIN PUMP

Forty male subjects between the ages of 20 and 40 years are needed. Measures of strength, flexibility, and anthropometry (i.e., percent body fat, body build, height, weight, etc.) will be taken at the City Rock facility between October 17 and November 14, 1992. Later these data will be compared to the scores obtained by the same subjects at City Rock's Pumpkin Pump (to be held October 31, 1992) to see which, if any, of the measures predict climbing performance. This experiment has been designed to use 10 subjects from each climbing category (i.e., recreational, intermediate, advanced and expert), consequently, it is imperative that people from each category take part. **WE NEED (MUST HAVE) SUBJECTS OF ALL ABILITIES - DON'T BE SHY!!** While you will not be paid for taking part in this project (in fact you will have to pay to take part in the Pumpkin Pump just like every *one else..* you will receive a large amount of information regarding your physiological make-up and how it compares to other sport climbers. Data collection will take approximately one to two hours, and in addition, you will have to take part in the Pumpkin Pump. Subjects will be selected on a first-come, first-served basis - don't procrastinate! If you are interested in taking part, please pick-up an informed consent form at the City Rock front desk, or call Jay Emoree at: days (415)354-7188, or evenings (408)335-5483 for more details regarding the study.

Appendix II

A campus of The California State University

College of Applied Sciences and Arts • Department of Human Performance
One Washington Square • San Jose, California 95192-0054 • 408/924-3010 • FAX 408/924-3053

AN EVALUATION OF TESTS FOR PREDICTING "ROCK" CLIMBING ABILITY IN MALE COMPETITION CLIMBERS

STATEMENT OF INFORMED CONSENT— FOR MUSCULAR STRENGTH, FLEXIBILITY, AND ANTHROPOMETRY

Invitation to Participate

You are invited to participate in a study investigating muscular strength, flexibility, anthropometric characteristics and recreational sport climbing performance.

Basis for Selection

You have been selected as a potential participant because you are an apparently healthy male 20 - 40 years old who is planning to, or already has, participated in the 1992 City Rock. Pumpkin Pump recreational climbing contest. Should you decide to participate in the study your response to a health history questionnaire will be reviewed by an Exercise Physiologist and, if acceptable, you will be asked to participate in the tests described below.

Purpose of the Study

The purpose of this study is to evaluate the ability of several different measures in predicting rock climbing performance as measured through scores obtained at a recreational climbing contest.

Explanation of Procedures

Test of Muscular Strength (approximately 10 minutes required)

This test will involve hanging from two 3-finger pockets on a training board for as long as you can. You will be allowed ample time to warm-up before the measurement is taken.

Tests of Flexibility (approximately 25 minutes required)

These tests will involve marking several joints (including ankles, hips, and bases of the big toes), and video taping you as you go through several ranges of motion. You will perform these ranges under your own power (i.e., no one will force you through a range of motion). You will be allowed ample time to warm-up prior to the testing. Hip adductor, flexors, and extensors, as well as ankle plantar and dorsiflexor flexibility will be measured. Later these tapes will be digitized and your ranges of motion for the before mentioned joints will be calculated via computer.

Tests of Anthropometry (approximately 30 minutes required)

These tests will include measures of skinfold thicknesses at triceps, scapular, axillary, supra-iliac, and abdominal sites, measures of circumferences at mid-upper-arm, and mid-calf, measurements of diameters at the elbow and knee, and measurements of extended arm breadth, body mass, and height.

These data will later be used to determine body composition, X and Y Hearn-Carter sonatype components, musculo-skeletal size, height to body mass ratio, and abducted arm breadth to height ratio.

Subjects initials _____

Appendix II (continued)

A campus of The California State University

College of Applied Sciences and Arts • Department of Human Performance
One Washington Square • San Jose, California 95192-0054 • 408/924-3010 • FAX 408/924-3033

Rock Climbing Performance Evaluation (4 hours)

On Saturday, October 31, 1992 you will take part (or already have) in the City Rock "Pumpkin Pump" recreational climbing contest. The score you receive will be used to order you with the other subjects in regard to rock climbing ability.

Risks and DiscomfortsTest of Strength

During the test you may experience muscle soreness, joint pain, increased heart rate, increased breathing rate, and increased body temperature. For up to two days after the test you may experience muscle soreness in your forearms.

Tests of Flexibility

Although you will be given ample time to warm-up and the tests demand that you only move through a range of motion you can create in a controlled manner, there is still risk of muscle and/or tendon strain during any of the before mentioned maneuvers. In addition, you will be burdened with having to remove the markings put on you for this analysis.

Tests of Anthropometry

Little risk is associated with these procedures; however, on occasion subjects have been pinched and/or bruised when skin fold thickness measurements are taken. In addition, while taking circumference measurements, you will be asked to flex your arm and your calf. There is a possibility of muscle cramping during this test.

Benefits of Participating in the Study

You will benefit from this study by receiving feedback on your own physiological make-up and how that make-up may help/hinder your rock climbing performance. In addition, you will be adding greatly to the dismally small body of knowledge regarding competitive sport climbing.

Assurance of Confidentiality

The results (but not your name) of this investigation may be used in research publication and/or presentation. Your right to confidentiality will be protected unless your express written consent is granted prior to the publication or presentation of these data.

Withdrawal from the Study

You may withdraw your consent and discontinue your participation in this study at any time (including during testing) without prejudice. You may also decline to answer any questions on the health summary questionnaire.

If you have any questions about the investigation now or during the testing, please do not hesitate to ask. If you have additional questions or in case of an emergency, please call Jay Embree 415/354-7188 (day) 408/335-5483 (evening), or Dr. Craig J. Cisar 408/924-3018. In the case of any complaints during or after the study, you may contact Serena Stanford, PhD., Associate Vice President of Graduate Studies and Research, at 408/924-2480.

Subjects initials ____

Appendix II (continued)

- CAMPUS OF THE LAKESIDE STATE UNIVERSITY

College of Applied Sciences and Arts • Department of Human Performance
One Washington Square • San Jose, California 95192-0054 • 408/924-3010 • FAX 408/924-3053

Consent

By signing this form, you are agreeing that:

- (a) you have decided to participate in this study having read the information above;
- (b) you understand the discomforts and risks involved;
- (c) you understand that you may withdraw at any time;
- (d) you understand that your name will be kept confidential except with your express written consent; and
- (e) you have received a copy of this consent form.

SIGNATURE _____ DATE _____

PRINT NAME _____

SIGNATURE OF WITNESS _____

SIGNATURE OF INVESTIGATOR _____

Appendix III

HEALTH SUMMARY QUESTIONNAIRE
FOR
AN EVALUATION OF TESTS FOR PREDICTING "ROCK" CLIMBING
ABILITY IN MALE COMPETITION CLIMBERS

Date _____

Name _____

Phone: Day _____ Evening _____

Home Address _____
 _____Work Address _____

Physicians Name _____ Physicians Phone _____

Date of last physical exam _____

Age _____ yrs. Height _____ ft. _____ in. Gender _____ Weight _____ lbs.

How many pounds have you ☐ gained or ☐ lost in the last year? _____**Joint and Muscle Status** Check the areas with which you are currently having problems.**Joints**

- ☐ Ankles
☐ Elbows
☐ Fingers
☐ Knees
☐ Low Spine
☐ Shoulders
☐ Toes
☐ Upper Spine/Neck
☐ Wrists
☐ Other _____

Muscles

- ☐ Abdominal region
☐ Chest
☐ Feet
☐ Forearm
☐ Low Back
☐ Lower Leg
☐ Shoulders
☐ Thighs
☐ Upper Arm
☐ Upper Back/Neck
☐ Other _____

Appendix III (continued)

Current Medication Usage List all medications you are using (both prescription and over the counter) at this time and the condition(s) you are managing with them.

<u>Medication</u>	<u>Condition</u>

Health Status Check all conditions you have now have or have had in the past.

- ☐ High Blood Pressure
 - ☐ Heart disease or dysfunction
 - ☐ Peripheral circulatory disorder
 - ☐ Lung disease or disorder
 - ☐ Arthritis or Gout
 - ☐ Edema
 - ☐ Epilepsy
 - ☐ Multiple sclerosis
 - ☐ High triglycerides
 - ☐ Diabetes or blood sugar level abnormality
 - ☐ Other
- ☐ Anemia
 - ☐ Hernias
 - ☐ Thyroid dysfunction
 - ☐ Pancreas dysfunction
 - ☐ Liver dysfunction
 - ☐ Kidney dysfunction
 - ☐ Neural dysfunction
 - ☐ High cholesterol
 - ☐ Acute infection

Activity Please list a typical weeks exercise (i.e., climbing, walking, running, lifting weights, stretching, etc.).

[illegible]

Appendix IV

AN EVALUATION OF TESTS FOR PREDICTING "ROCK" CLIMBING ABILITY IN MALE COMPETITION CLIMBERS

DATA SHEET

Name _____ Date _____ Subject _____

Birth Date _____ Competition Score _____ # of routes completed _____

Flexibility

Left hip Adductors _____, Flexors _____, Extensors _____

Left Ankle Plantar flexion _____, Dorsiflexion _____

Right Hip Adductors _____, Flexors _____, Extensors _____

Right Ankle Plantar flexion _____, Dorsiflexion _____

Strength

Hang Time _____seconds

Anthropometry

Body Mass _____lbs Height _____in Arm Breadth _____cm

Right Arm Circumference _____cm, Left Arm Circumference _____cm

Right Elbow Diameter _____cm, Left Elbow Diameter _____cm

Right Knee Diameter _____cm, Left Knee Diameter _____cm

Skinfolds

Triceps _____

Sub-scapular _____

Mid-axillary _____

Supra-iliac _____

Abdominal _____

Calf _____

Appendix V

A campus of The California State University

College of Applied Sciences and Arts • Department of Human Performance
One Washington Square • San Jose, California 95192-0054 • 408/924-3010 • FAX 408/924-3053

September 9, 1992

San Jose State University
Department of Human Performance
One Washington Square
San Jose, CA 95192-0054

To Whom It May Concern:

This Letter is to confirm that the City Rock Gym of Emeryville, California has granted permission to Jay Embree to 1) collect data (to include measures of strength, flexibility and anthropometry on forty male subjects) on the premisses of City Rock and 2) use the scores obtained by these same subjects (subjects will have also given consent individually) at City Rocks' "Pumpkin Pump", (a recreational sport climbing contest, to be held October 31, 1992) in the analysis of these data.

The Pumpkin Pump is a yearly event organized entirely by City Rock, neither Jay Embree nor San Jose State University staff have contributed to or encouraged the organization of this event.

Sincerely,

City Rock Gym
1250 45th St. Suite 400
Emeryville, CA 94608