MODIFICATIONS OF FORCE DISTRIBUTION IN NOVICE ROCK CLIMBING TECHNIQUE

G. Wayne Marino and Patrick Kelly
Department of Kinesiology
University of Windsor
Windsor, Canada

Introduction

Learning to rock climb is largely a matter of learning how to use the feet, to keep in balance over them, and to relay as little as possible on the arms and hands. Climbing should be performed primarily with the legs and feet because the lager postural muscles involved have greater endurance than those in the upper body. In addition, balance is a very important element of climbing technique. The objective is to keep the weight over the base of support. Often, climbers move out of balance and place demands on the hands and arms, as some climbs require, but ideally the climber returns to a balanced position as quickly as possible to rest the arms and hands.

It is apparent that before serious rock climbing is attempted, a prospective climber should undergo instruction from experts. However, perusal of the literature indicates that much of the information available is based on the experience and subjective observations of climbing instructors.

The information available in the literature deals primarily with climbing technique under various conditions. For example, Loughman (1981) stated that climbing should be performed primarily with the legs and feet, because they are stronger than the arms and hands. Robbins (1973) compared the climbing of a vertical rockface to climbing a ladder. In such climbing, the legs do the heavy work and the arms are used for balance and to help maintain a vertical posture. Thus,balance is a critical element of rock climbing technique. Maintaining a strategic position of balance and not hugging the rockface was also emphasized by Banks (1978). Balance was emphasized because leaning into the rock impedes vision. Climbers who lean in cannot see their feet and also have only a limited view of the rock above. Thus, they are forced into greater reliance on the hands and arms.

Proper footwork is vital and often the key to harder climbs. The foot must be moved and placed carefully and deliberately and the heels should be kept down to reduce the tendency to slip off the foothold. Chisnall (1985) described the most effective foot technique used in face climbing. The technique is called 'edging' and involves placement of the inside front edge of the shoe on the rock hold. In this position, most of the body weight is supported on the ball of the foot and big toe. Toeing in and perpendicular edging are not recommended, as they result in a more taxing position for the muscles of the foot and lower leg.

Good footwork has been stressed as being particularly important to female climbers (Loughman, 1981). This is because of the necessity to conserve upper body strength for the difficult positions of a climb. Strength is an asset in climbing, but even the strongest and most powerful men and women must be conscious of technique. Climbers may rely on strength on short and easy routes, but must conserve strength by using sound technique on more difficult or multi-pitch routes (Loughman, 1981).

In summary, a review of the limited information available on rock climbing points out the importance of several factors. Balance over a small foothold is critical in the sport of climbing. In addition, it is essential that most of the body weight be supported by the legs during a large proportion of the climbing time. This is essential in order to conserve upper body strength for the most difficult parts of the climb. There is little evidence available of objective research results pertaining to the techniques of rock climbing. Thus, it appears that studies of climbing technique and the effects of basic instruction on technique improvement are warranted.

The purpose of the present study was to investigate the effects of climbing instruction on the force distribution characteristics of novice male and female rock climbers in a modified climbing task.

Methods

In order to measure the forces exerted by both the upper body and lower body during a simulated climbing task, apparatus was designed to measure each force independently. The simulated foothold apparatus consisted of a triangular-shaped wooden structure with two 4 cm ledges. These ledges were used to provide footholds for the 60 degree, 90 degree and 120 degree climbing tasks. The entire apparatus was mounted on an AMTI force platform. Thus, the force platform was used to measure the ground reaction forces created when the subject stood on the simulated foothold apparatus.

The handhold apparatus consisted of an aluminum handle attached to a force transducer and suspended form the ceiling by climbing webbing attached to two Jumars by way of Carabiners. The Jumars were, in turn, clamped to two lengths of rope anchored to the girders of the ceiling. A third webbing sling served as a backup in the unlikely event of anchor failure. All anchors were equalized to avoid stressing individual components, and each was backed up for safety. The use of this type of adjustable apparatus allowed for the measurement of the amount of weight supported by the upper body and hands at each of the three slope angles with only minor adjustments.

Two groups of subjects were recruited for participation in this study. These consisted of eleven males and five females with no previous experience in rock climbing. Each of the groups (males and females) was tested in a simulated rock climb at each of the three angle faces (60 degrees, 90 degrees, and 120 degree slopes) under conditions of both no instruction and instruction. Thus, there were three independent variables used in the study: a) males vs females, b) slope difficulty and c) no instruction vs instruction.

There were two dependent variables measured in the study. The first was the amount of weight supported by the lower body during a simulated rock climb. The second was the amount of weight supported by the upper body during the same climb. In addition, a ration of weight supported by the lower body over weight supported by the upper body was determined for each subject in the pre and post instruction conditions.

All testing took place in the biomechanics laboratory of the Department of Kinesiology at the University of Windsor. Subjects were allowed to view the apparatus and were told that the task was a simulated rock climb. They were informed that the objective was to climb up onto the apparatus and remain there until asked to step down. When they felt ready, they were instructed to proceed with their first trial. In any trial where a subject slipped or did not maintain contact with both the foothold and handhold devices, the subject was allowed to repeat the trial with no further instruction. Subjects performed three trials each at each of the three slope instruction. Subjects performed three trials each at each of the three slope faces chosen for use in the study. Following the completion of these trials subjects were given specific instructions as to how the task should be attempted based on rock climbing principles. Foot placement, leg positioning, leg motion, heel angle, hand and arm position, and balance instructions were included as the key points in climbing technique. In addition, subjects were instructed that under normal conditions climbers should make maximal use of the legs in supporting the body and minimal use of the arms. Following the instructions, each subject again was given three trials at each of the 60 degree, 90 degree, and 120 degree slopes.

Statistical analysis included the use of dependent samples t-tests to compare pre-instruction and post-instruction performances. In addition, the lower body to upper body force ratios were subjected to three-way analysis of variance with repeated measures on two within-group variables. Thus, main effects F rations were determined for male vs female groups, for the levels of slope difficulty, and for the pre and post instruction trials. In addition, interactions between factors were also investigated.

Results and Discussion

Force-time profiles were developed for each trial in the simulated rock climbing task for both the lower body and upper body contributions. The force values used to represent subject performance were the maximum values recorded for each trial. These were averaged for the three trials at each face angle and the means were used in subsequent statistical analysis.

The mean values for each of the slopes tested both before and following instruction are listed in Table 1.

Table 1

Mean Force Maxima for Upper and Lower Body Force Contributions for Pre and Post Instruction Trials

SLOPE	CONTRIBUTION	PRE-INSTRUCTION	POST-INSTRUCTION	T-RATIO
60°	Lower Body	876 N	1000 N	1.01
	Upper Body	214 N	100 N	2.41*
90°	Lower Body	707 N	813 N	1.67
	Upper Body	366 N	211 N	2.75*
120°	Lower Body	671 N	814 N	1.89
	Upper Body	433 N	242 N	2.95*

* Significant at $P < .05$

It was found that for each of the slopes tested the subjects performed more effectively following climbing instructions. However, only in the case of the upper body force contributions were the differences statistically significant. In each case, the climbers were able to significantly reduce the amount of force exerted on the handhold apparatus.

In order to assess the combined contributions of the upper and lower body in the climbing task, ratios were developed of foothold force/ handhold force. The mean values for each of the slopes in the pre and post instruction trials are listed in Table 2.

Table 2

Mean Foothold Force/Handhold Force Ratios
for Pre and Post Instruction Trials

SLOPE	PRE-INSTRUCTION	POST-INSTRUCTION	T-RATIO
60°	4.62	11.75	3.52*
90°	1.95	4.10	3.21*
120°	1.91	6.64	3.08*

* Significant at $P < .01$

It was found that in each case, subjects were able to create significantly higher foothold/handhold force ratios following instructions. Thus, it appears that simple instruction concerning technique emphasis is instrumental in producing almost immediate improvements in climbing technique.

In an effort to more carefully scrutinize the data to look at the effects of climbing instruction given to male and female subjects performing at each of the three slopes, the force production ratios were subject to t three-way ANOVA with repeated measures on two factors (pre vs post instruction and slope degree). The ANOVA is summarized in Table 3.

Table 3

Summary of Three-Way ANOVA with Repeated Measures on Two Factors

VARIABLE	F-RATIO
Gender (P)	.322
Instruction (Q)	20.750 *
P x Q	.224
Slope (R)	10.748 *
P x R	1.633
Q x R	1.467
P x Q x R	.181

* Significant at P < .01

The variable gender was found to produce no significant differences (F = .322). Thus, there were no differences between male and female subjects in the foothold/handhold force ratio. It appears, therefore, that males and females performed the novice rock climbing task in a similar manner under all conditions of instruction and slope difficulty. As expected, the variable instruction, previously analyzed through the use of dependent samples t-tests, produced statistically significant differences (F = 20.75). Analysis of the raw data revealed significantly better post-instruction technique. The variable slope also produced significant differences (F = 10.748). The differences were found to exist between the easiest task (60 degrees) and the two more difficult tasks (90 degrees and 120 degrees). This result was not unexpected as the easier 60 degree slope allowed subjects a better view of the handhold and allowed the use of a somewhat larger contact area between the foot and the foothold apparatus. No significant interactions were found between or among the various levels of the three independent variables.

Summary and Conclusions

The purpose of the study was to investigate the effects of instruction on the rock climbing technique of male and female subjects performing a simulated rock climbing task with three degrees of slope difficulty. A review of available literature revealed the importance of balance and the use of the legs rather than arms to support the body weight. Thus, a relatively large ratio of foothold/handhold force should be indicative of better technique. Based on the results of this study and with the limitations of the study in mind, it appears that the following conclusions are warranted:

1. Instruction produced significant changes in the efficiency of rock climbing technique.
2. There are no significant differences in technique efficiency between novice male and female rock climbers.
3. Slope difficulty produces significant differences in the efficiency of rock climbing technique.

References

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