Differences in Climbing-Specific Strength Between Boulder and Lead Rock Climbers

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Abstract

Fanchini, M, Violette, F, Impellizzeri, FM, and Maffiuletti, NA. Differences in climbing-specific strength between boulder and lead rock climbers. *J Strength Cond Res* 27(2): 310–314, 2013—The purpose of this study was to compare maximal muscle strength and rapid force capacity of finger flexors between boulder and lead climbers of national-international level. Ten boulder (mean ± *SD*, age 27 ± 8 years) and 10 lead climbers (age 27 ± 6 years) volunteered for the study. Ten nonclimbers (age 25 ± 4 years) were also tested. Isometric maximal voluntary contraction (MVC) force and rate of force development (RFD) produced in "crimp" and "open-crimp" hand positions were evaluated on an instrumented hold. Climbers were stronger than nonclimbers. More interestingly, MVC force and RFD were significantly greater in boulder compared with lead climbers ($p < 0.05$), in both crimp and open-crimp positions. The RFD was the most discriminatory outcome, as the largest difference between boulder and lead climbers (34–38%) was observed for this variable. The RFD may reflect the specific requirements of bouldering and seems to be more appropriate than pure maximal strength for investigating muscle function in rock climbers.

Key Words rate of force development, hold, crimp, maximal voluntary contraction

Introduction

Rock climbing is a popular competitive and recreational sport activity (15,20) that can be performed on natural and artificial walls in both outdoor and indoor environments. Lead climbing and bouldering are the 2 most practiced climbing styles. Lead competitions are performed on high walls (12–18 m), and the effective climbing time is longer compared with bouldering attempts (27). Bouldering consists of a number of short technical routes (called "problems") that are climbed without a rope but with landing mats to ensure safety. Bouldering competitions are performed on low walls (4–5 m), and the score of the performance is given from the number of attempts "to solve" (climb) the problems, which provide the points for the final ranking. Despite substantial differences between boulder and lead climbing in terms of physiological, technical, and tactical requirements, physical characteristics have never been compared between climbers of these 2 specialties.

Finger-flexor maximal strength of climbers has frequently been compared with nonclimbers (5,6,8,9,13,18,22), because it is considered an important determinant of rock climbing performance. However, it has been demonstrated that handgrip strength measures have a low discriminatory ability (9,25), probably because of their poor specificity to climbing. For this reason, specific dynamometers that more closely mimic the climbing grip styles have been developed (9,26), which are able to detect differences in finger-flexor maximal muscle strength between climbers and nonclimbers (8–10,14,18). Interestingly, it has been suggested that the time required for producing force could even be much more discriminatory than pure maximal muscle strength (7). As pointed out by Watts et al. (23), the hand-hold "contact strength," which is defined as the ability to quickly grasp a hold and grip to it (11), can be viewed as a possible important determinant of bouldering performance. In this regard, the rate of force development (RFD), which is an essential functional parameter for activities requiring rapid force capacities (2), could be more appropriate than maximum muscle strength (24) for investigating differences in muscle strength profile between boulder and lead climbers.

The aim of this study was to compare climbing-specific maximal muscle strength and rapid force capacity of finger flexors between high-level boulder and lead climbers, and nonclimbers. Because of the specificity of rock climbing specialties, we hypothesized that boulder climbers would exhibit higher RFD than lead climbers do. We also expected greater strength capabilities in climbers than in nonclimbers.

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Table 1. Subject characteristics by group.*

	BC ($n = 10$)	LC ($n = 10$)	NC ($n = 10$)
Age (y)	26.8 (7.6)	27.0 (5.5)	24.7 (3.9)
Body height (cm)	180.4 (8.1)	179.1 (5.5)	179.6 (6.2)
Body mass (kg)	69.7 (9.2)	69.3 (7.4)	78.2 (4.1)†
Climbing experience (y)	12.2 (7.7)	12.3 (3.2)	
Climbing ability (au)	10.8 (0.8)	10.8 (1.2)	
Climbers per grade (n)			
7b	2	0	
7b+	2	0	
7c	2	0	
7c+	2	2	
8a	2	2	
8a+	0	2	
8b+	0	2	
8c	0	2	

*Results are given as mean (*SD*).
†$p < 0.05$.

Methods

Experimental Approach to the Problem

To examine potential differences in muscle strength profile between boulder climbers, lead climbers, and nonclimbers, a cross-sectional case-control study design was used, where the group was the independent variable. Each subject participated in 1 laboratory test session, which consisted of maximal-effort rapid isometric contractions performed on an instrumented climbing hold in 2 different hand positions ("crimp" and "open-crimp"). Only the dominant side, as determined using a questionnaire based on daily-living and sport activities, was evaluated. The following strength outcomes were considered as the dependent variables: crimp maximal voluntary contraction (MVC) force, crimp RFD, open crimp MVC force, and open crimp RFD. Testing took place in-season, and climbers were asked to maintain their regular training and competition regimens for 2 months before their test date. All the subjects received standard testing instructions (nutrition, hydration, sleep) verbally and written, and were asked not to take part in any demanding physical activity for 2 days before testing.

Subjects

A total of 20 French male rock climbers participating in national and international competitions of boulder or lead climbing volunteered to participate in this study and were, respectively, allocated to BC ($n = 10$) and LC ($n = 10$) groups (Table 1). Climbing ability was determined as the most difficult self-reported climb ever achieved, which was rated using the French grading system. Because bouldering problems are considered more difficult compared with lead routes of the same grade (21), 2 different grading scales were used for boulder and lead climbing. For a qualitative comparison, we used the arbitrary criterion adopted among climbers, which considers that a given bouldering grade is 1–2 grades higher than lead (e.g., a "6a" bouldering is considered equivalent to a "6b" lead). Climbing ability was then converted to a score according to the classification proposed by Brent et al. (4). Ten physically active volunteers without experience in rock climbing (sport science students) served as the nonclimbers (NC). All the subjects signed a consent form, which along with the study protocol was approved by the Institutional Review Board of the University of Burgundy.

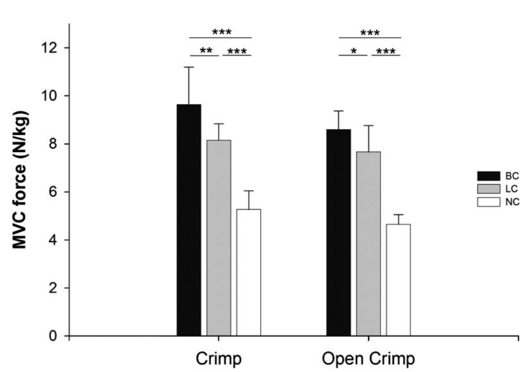

Figure 1. Maximal voluntary contraction (MVC) force of finger flexor muscles by group and hand position. Mean and *SD*. *$p < 0.05$; ***$p < 0.001$.

Procedures

Muscle Strength Assessment. Isometric MVC force and peak RFD were assessed using an S-shaped strain gauge force transducer (SBB, Tempo technologies, Taipei, Taiwan) mounted on a hand-made L-shaped climbing hold. The subjects were seated on a heavy height-modifiable chair, with the hips and knees at 90°, and the dominant shoulder and elbow fully extended (i.e., the arm-trunk angle was 180°). After a climbing-specific warm-up period of 10 minutes, which included familiarization with the strength-testing equipment and procedures, the subjects were carefully instructed to develop their force on the climbing hold as fast and as hard as possible for approximately 3 seconds. They were verbally encouraged and supervised by the same

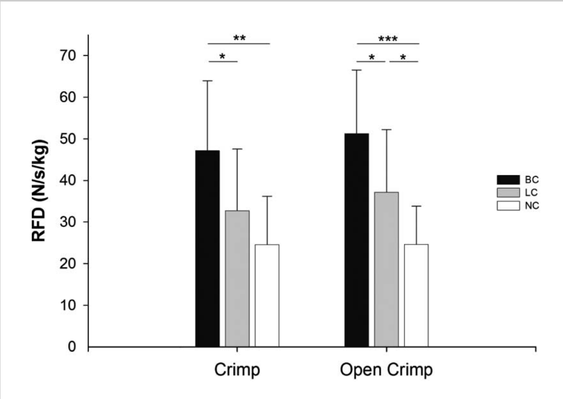

Figure 2. Rate of force development (RFD) of finger flexor muscles by group and hand position. Mean and *SD*. $*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

examiner throughout the testing session. Three trials for each of the 2 climbing-specific hand positions were performed: the crimp, in which the thumb was in contact with the index finger (19) and the open-crimp, in which the thumb was not allowed to make contact with the other fingers (7). The 6 maximal trials were randomly presented and separated by 1-minute recovery periods.

The force signal was recorded at a sampling frequency of 1 kHz and analyzed using a commercially available software (Tida, Heka elektronik, Lambrecht/Pfalz, Germany). Isometric MVC force and peak RFD (i.e., the highest positive value from the first derivative of the force signal) for the crimp and open crimp positions were calculated from the force-time traces and subsequently normalized to body mass.

Statistical Analyses

Data are presented as mean and *SD*. For the dependent variables used in this study, intraclass correlation coefficients were >0.90. Differences in the dependent variables between BC, LC, and NC were examined using a 1-way analysis of variance with "group" in 3 levels as the independent variable. When a significant *F*-value was found, the least significant difference post hoc test was applied. Effect size (partial eta squared, η^2) was also calculated and values of 0.01, 0.06, and >0.15 were interpreted as small, medium, and large, respectively. Additionally, percent differences between BC and LC were presented with 95% confidence intervals, after log transformation of raw data. The alpha level was set at 0.05. The analyses were performed using SPSS statistical software (Version 13.0, SPSS Inc., Chicago, IL, USA).

Results

Age and height were comparable in the 3 groups (Table 1). The main factor group was significant for body mass ($p = 0.016$, $\eta^2 = 0.26$), with post hoc tests showing that NC were heavier than both LC ($p = 0.01$) and BC ($p = 0.014$). Climbing experience in terms of years of practice and climbing ability were comparable for BC and LC.

Isometric MVC force for both crimp and open-crimp conditions differed significantly between groups (Figure 1). The main factor for crimp MVC force was significant ($p < 0.0001$, $\eta^2 = 0.76$); BC showed higher values compared with LC ($p = 0.005$), whereas NC showed the lowest values ($p < 0.0001$). Similarly, between-group differences in MVC force were found for the open-crimp position ($p < 0.0001$, $\eta^2 = 0.83$); BCs were stronger than LC ($p = 0.015$), and NC had the lowest values ($p < 0.0001$).

The main factor group was significant for RFD measures obtained in both crimp ($p = 0.006$, $\eta^2 = 0.31$) and open-

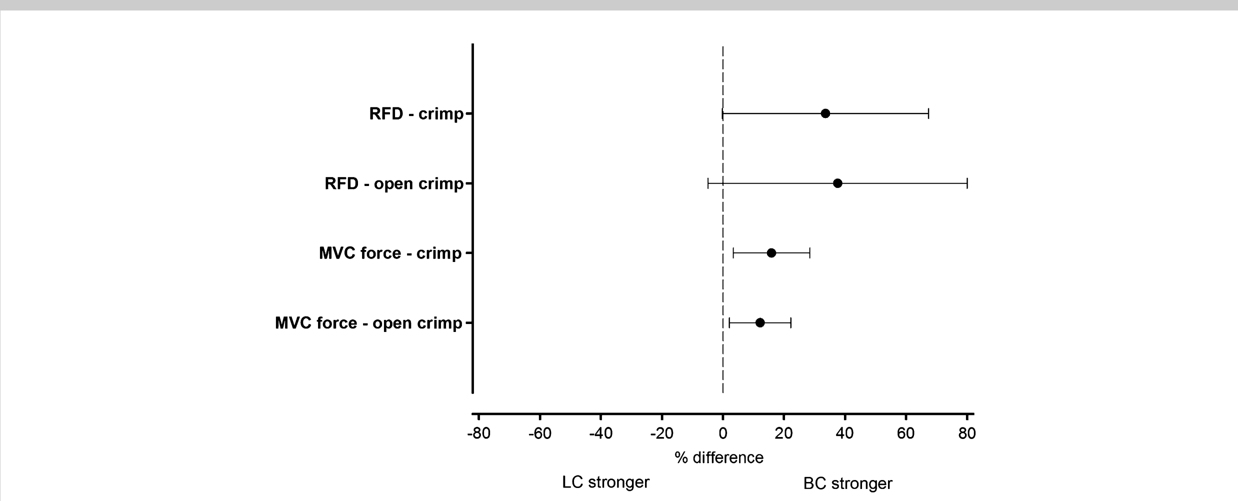

Figure 3. Percentage of difference between boulder (BC) and lead climbers (LC) in finger-flexor strength outcomes (95% confidence intervals).

crimp ($p = 0.001$, $\eta^2 = 0.42$) conditions (Figure 2). In the crimp position, BC showed higher values compared with both LC ($p = 0.036$) and NC ($p = 0.002$). Similarly, BCs were stronger than LCs ($p = 0.027$) and NC ($p < 0.0001$), and LCs were stronger than NCs ($p = 0.047$) in the open-crimp condition. Overall, BCs were stronger than LCs in most of the strength measures (Figure 3), and group differences ranged between 12.2% (open crimp MVC force) and 37.6% (open crimp RFD).

Discussion

The main finding of this study was that boulder climbers displayed greater finger-flexor maximal muscle strength and rapid force capacity compared with their lead counterparts. Although some authors have suggested the importance of rapid force production for rock climbing (24), this is the first study to examine differences in RFD between athletes from the 2 main climbing specialties. Interestingly, RFD was the parameter that most strongly differentiated boulder from lead climbers. Additionally, climbers were stronger than nonclimbers in the majority of strength measures, with large differences between BC and NC. To our knowledge, this is also the first study in which climbers with high climbing ability were considered. Indeed, the average level of the climbers tested in this study (7c+ and 8a+ for bouldering and lead, respectively) was higher compared with previous investigations (8–10,14,18). However, as with all cross-sectional research studies profiling specific athletic populations, we cannot separate the possibility that long-term training and competition within a climbing specialty caused the between-group differences from the possibility that athletes self-selected their climbing specialty based on inherent physiological abilities that predisposed them to success.

It is a common belief among climbers that finger-flexor muscle strength is a determinant factor in boulder climbing performance. For this reason, bouldering *problems* are frequently included into lead routes to increase the difficulty and intensity of lead climbing competitions. Recently, White and Olsen (27) examined a national bouldering competition using video time-motion analysis, and suggested that strength requirements of this discipline are greater compared with lead because (a) the duration of the activity is shorter (30 seconds for bouldering vs. 2–7 minutes for lead), (b) the number of attempts is higher (multiple for bouldering vs. single for lead), (c) the time spent in static positions is less (25 vs. 38% of total climbing time for bouldering and lead, respectively), (d) movements are more "explosive" for bouldering than for lead climbing (27). Similar conclusions have been drawn by La Torre et al. (12) who compared data from national bouldering competitions with data of lead climbers obtained in the literature. Furthermore, there is good evidence that overhanging walls (10° of inclination) such as those adopted in boulder climbing require upper limb muscles to exert higher forces (62% of the body mass on the hand-holds) compared with vertical routes, where the distribution of forces is predominantly on the lower limbs (57% of the body mass on the feet holds) (16).

Contrary to lead climbing, bouldering is characterized by movements requiring rapid muscle contractions. In fact, body stabilization after dynamic movements requires the generation of high levels of force in a relatively short time by finger-flexor muscles. For this reason, it has been suggested that RFD could be an important outcome and a discriminatory variable in the functional assessment of rock climbers (24). The RFD, which can be viewed as an expression of rapid muscle force, is defined as the rate of increase in contractile force at the onset of contraction (1). Therefore, RFD produced in the early phase of a voluntary contraction describes the ability to rapidly develop muscular force (3). Interestingly, the largest difference between BC and LC was observed for RFD in this study. Boulder climbers frequently use specific apparatus, such as campus boards or even special climbing postures (e.g., climbing with the feet hanging and dropping down to bottom holds) to train rapid force capacity. This can potentially increase the RFD in finger-flexor muscles via chronic neural and muscular adaptations. For example, there is evidence that ballistic-type strength training can induce specific adaptations of the motor unit discharge rate, such as an increase in the number of discharge doublets in the firing pattern, hence increasing the RFD (2). Because the athletes tested in this study had a long experience of climbing, the difference in RFD between BC and LC can reflect the adaptations induced by years of explosive-type muscle actions in the former group, even though the possible influence of genetic predisposing factors cannot be ruled out. Lead climbers, on the contrary, are required to finely adjust the force applied on the holds by modulating the contraction intensity, with the objective to delay the occurrence of fatigue and to prepare for ensuing movements. The difference between BC and LC in RFD (38% in open crimp and 34% in crimp position) compared with MVC force (12% in open crimp and 16% in crimp position) suggests, as hypothesized by Watts (24), that the measure of RFD is potentially more important and appropriate for cross-sectional and longitudinal assessments of climbers. Future studies should consider RFD when assessing specific muscle function in rock climbers, particularly in boulder climbers.

Previous studies have shown that differences between climbers and nonclimbers can be found by using specific strength outcomes, such as the MVC force obtained on instrumented holds or custom-made dynamometers with load cells placed in the vertical position (9,10,18). One of the supposed limits of experienced climbers is the inability to maintain the hand position on the hold (24). Because climbing requires isometric contractions of finger-flexor muscles, this probably induces strength improvements specific to the positions (e.g., angles and muscle length) adopted during climbing. Accordingly, all climbers showed greater MVC scores compared with NC in both crimp and open-crimp positions. This is in line with the findings of 2 previous studies (9,14) that have reported differences in finger-flexors MVC strength between climbers and nonclimbers. The results of this study clearly indicate that muscle strength evaluation (and probably also strength training) for rock climbing should be more specific.

Practical Applications

The present findings suggest that RFD, which relies on the capacity of fast neuromuscular activation at contraction onset, may reflect the specific requirements of bouldering but not of lead climbing. This may have multiple implications for both sport scientists and rock climbing coaches. Finger-flexor muscle testing and training should be performed separately for boulder and lead climbers, and they should not be considered as a single category anymore. The assessment of isometric RFD on an instrumented hold, which is simple and straightforward, should be preferred to pure maximal strength in boulder rock climbers. We also propose that boulder athletes should use high-resistance explosive contractions to specifically train rapid force capacity of finger-flexor muscles. On the other hand, because muscle strength is less important for lead climbing, more attention should be paid to the development of other physical characteristics such as muscle endurance (17).

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