EFFECT OF HOLD SLOPER ANGLE AND HOLD DEPTH ON MAXIMAL FINGER FORCE CAPACITY OF ROCK CLIMBERS

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The purpose of this study was to identify the combined effect of sloper angle and hold depth on maximal finger force capacity (MFFC) of rock climbers. Eight experienced climbers performed vertical maximal finger contractions on four different size of holds (1, 2, 3 and 4 cm) with five different sloper angles from 0° to 40° (with 10° increment). The results of this study showed that mean MFFC ranged from 25.2 ± 4.1 kg to 49.1 ± 9.0 kg and differed significantly according to the sloper angle and hold depth. Besides, decreasing the hold depth and increasing the sloper angle of a hold leads to a fall of the MFFC. These results confirm the previous findings of hold depth effect and improve them for sloper holds by pointing out the interaction between hold depth and slope angle.

KEY WORDS: rock climbing, grip, sloper angle, performance.

INTRODUCTION: Over the last decades, rock climbing standards and levels of difficulty have progressed enormously. Nowadays, difficult routes are mostly on overhanging cliffs and composed primarily of tiny holds. On overhanging routes, large percentage of the body weight is supported by fingers. Therefore finger grip strength plays crucially important role in rock climbing. It is showed that inability to generate the necessary finger force on a hold is one of the main reasons of failure on a climbing route. Many studies have focused on differences between grip techniques and maximal fingertip force of rock climbers (Quaine et al., 2011; Schweizer & Hudek, 2011). Nevertheless, only a few studies have concentrated on hold size and maximal finger force capacity (MFFC) of rock climbers (Amca et al., 2012; Bourne et al., 2011). On the other hand, the relationship between hold sloper angle and MFFC has never been assessed. The purpose of this study was to understand the combined effect of sloper angle and hold depth on vertical MFFC of rock climbers.

METHODS: Eight experienced and well trained climbers (mean French 7c red point level) participated in this study. A specially designed apparatus instrumented with a tension-compression load cell was used to measure applied vertical force on holds. Force data was amplified and recorded at 500 Hz with a Simulink program. Five wooden flat holds with various constant sloper angles (from 0° to 40° with 10° increment) were used and four hold depths (1 cm, 2 cm, 3 cm and 4 cm) were considered. The depth of the hold's grip surface was carefully adjusted by placing 1 mm thick card panels on the hold. Participants were standing up, facing the wall and parallel to the hold plane. The height of the test hold was adjusted and participants were positioned with 110° of shoulder flexion, 60° of shoulder horizontal abduction and 70° of elbow flexion (vertical forearm). Participants were instructed to place the fingertips in contact with the backside of the hold and they were allowed to choose between open and half crimp grip techniques. Participants were asked to pull the hold maximally in vertical direction and performed maximal force for each condition. They performed three trials for each condition (5 sloper angles x 4 depths) which are separated by rest periods (1.5 min between trials and 5 min between conditions) and the highest one was considered as MFFC. As in the real climbing conditions climbing chalk was used in the test and excess chalk on the holds was brushed after each trial. Experiments were divided into two sessions and performed in two different days. Test conditions were randomised to avoid any learning or fatiguing effects.

Force data was filtered with a zero-lag low pass Butterworth digital filter (second order, 10 Hz). MFFC values were determined for each condition. All measured values were reported as means and standard deviations (±). Repeated Measure Analyses of Variance (ANOVAs) were used to analyse the effect of ''sloper angle'' and ''hold depth'' on MFFC. Tukey post-hoc test was used to classify differences when ANOVA showed a significant effect (P<0.05). All calculations were performed by utilizing custom written scripts in MATLAB (The Math Works, Inc., USA) and Statistica (StatSoft, Inc. 1984-2005) was used for statistical analysis.

RESULTS: The participants mostly preferred to use half crimp grip on 1 cm and 2 cm holds. On the other hand, open grip was used on the larger holds. The mean maximal finger forces applied on each tested hold are presented in Figure 1. MFFC ranged from 25.18 ± 4.12 kg to 49.14 ± 9.00 kg and differed significantly according to the sloper angle and hold depth ($F_{3,21}$ = 41.7, $F_{4,28}$ = 48.0, P<0.05). Additionally, a significant interaction between sloper angle and hold depth was observed ($F_{12,84}$ = 2.2, P<0.05). It was shown that MFFC decreased with increasing sloper angle of hold surface and decreasing hold depth. For the 3 cm and 4 cm holds, the effect of sloper angle on MFFC was not significant from 0° to 30° but a significant decrease was noticed at 40° holds. On the other hand, a significant decrease was noted after 20° sloper angle at smaller holds (1 cm and 2 cm). In addition, a small decrease was observed between 4 cm and 3 cm holds for all sloper angle conditions but they were not significant. Only for 20° and 30° sloper holds, MFFC decreased significantly between 3 cm and 2 cm hold depths. When the depth decreased to 1 cm, a significant MFFC decrease was observed for all sloper angle conditions.

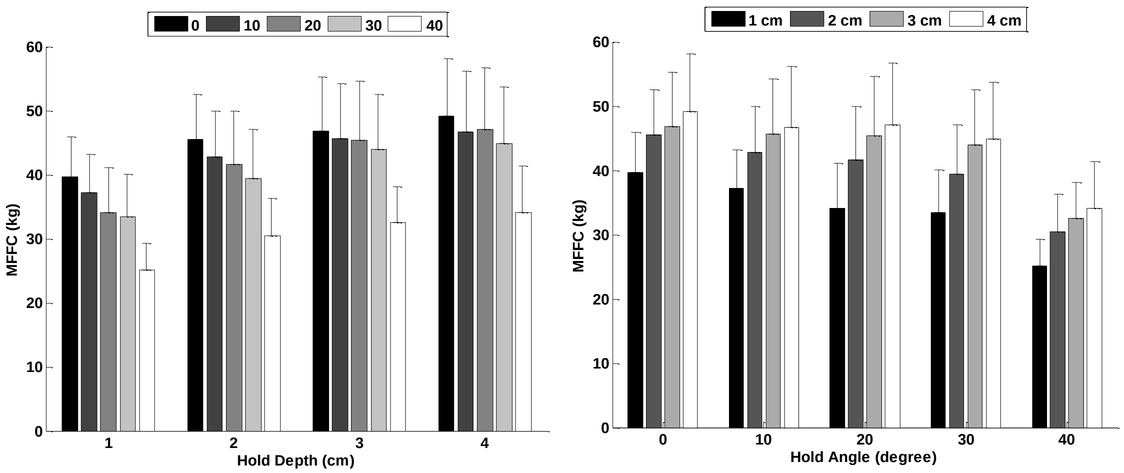

Figure 1: Mean maximal finger force capacities (kg) and standard deviations

DISCUSSION: The results of this study showed that climbers generally tend to use half crimp grip to apply maximal forces on small holds even if the holds are sloper. This behaviour is in line with the previous studies which have not reported any significant differences between open and half crimp grip techniques and have shown that the climbers choose between grip techniques according to optimise the finger-hold contact (Amca et al., 2012; Quaine & Vigouroux, 2004; Schöffl et al., 2009).
The result of mean maximal vertical finger force on 1 cm and 0° slopper hold in accordance with the previous studies (Amca et al., 2012; Quaine & Vigouroux, 2004) which were reported values between 360 N and 450 N on the same hold. On the other hand, although some participants performed similar forces on larger holds (2-4 cm) with 0° slopper angle, mean results were lower than the previous studies (Amca et al., 2012). Different experimental designs, level of climbers and training adaptations between these studies would possibly cause these lower maximal force values.

Concerning the effect of sloper angle on MFFC, it was showed that vertical MFFC decreased with increasing hold angle and the decrease was more notable on smaller holds. Similar results have also been confirmed for applied forces on a hold during a climbing session by Fuss et al. (2013).

CONCLUSION: This study showed that increasing sloper angle decrease the MFFC on holds and this decrease was more remarkable on small holds. On larger holds, the effect of sloper angle was significant after 30°. Moreover, it was observed that MFFC decreases according to the decreasing hold depth and this decrease are major on more sloper holds. These results pointed out that the MFFC is effected by both hold depth and slope angle and an interaction is available between these factors. This interaction will be clearly defined with further examinations and by the way force capacity estimation models can be developed. These models will be used by trainers to observe the performance of their athletes and set training programs regarding their weak points. Further, such models can be improved by testing the relationship between hold angle and maximal anterior-posterior force capacity, which may be used to classify climbing holds by means of defining hold difficulty.

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