Relationship between climbing specific grip techniques, hold depth and maximal finger force capacity of rock climbers

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Introduction

When climbers see or touch a hold, they have an idea in their mind about the possible gripping positions and how hard will be the grips! Then, they decide on a grip.

How they decide on the grip technique?

Which parameters effect the choice of grip type?

How they judge the difficulty?

Is it possible to create an objective mathematical model to determine the difficulty of a hold?
Hypothesis

Hold depth and multidirectional force capacity could explain the preference of climbers to use one or another grip technique.

An objective mathematical model can be created to determine the relationship between hold depth and finger force capacity.

Purposes

• to understand the effect of climbing grip techniques and hold depths on Maximal Finger Force Capacity (MFFC) in both vertical and anterior-posterior directions.

• to define MFFC as a function of hold depths.
Method

Subjects
• 10 experienced climbers

<table>
<thead>
<tr>
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<th>Mean ± sd</th>
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</thead>
<tbody>
<tr>
<td>Climbing level</td>
<td>7c / IX</td>
</tr>
<tr>
<td>Age</td>
<td>22.3 ± 4.5</td>
</tr>
<tr>
<td>Body Weight (kg)</td>
<td>72.7 ± 5.7</td>
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<tr>
<td>Height (cm)</td>
<td>177.6 ± 5.3</td>
</tr>
<tr>
<td>Body Mass Index (BMI)</td>
<td>23.4 ± 1.8</td>
</tr>
<tr>
<td>Hand Length (cm)</td>
<td>19.5 ± 0.7</td>
</tr>
<tr>
<td>Forearm Length (cm)</td>
<td>28.3 ± 1.4</td>
</tr>
<tr>
<td>Forearm Circ. max. (cm)</td>
<td>30.2 ± 1.3</td>
</tr>
</tbody>
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Handholds
• Wooden, flat grip surfaces, rounded edge
• Hold depths: 1, 2, 3, 4 cm

Grip Techniques

- Slope
- Half crimp
- Full crimp (with thumb)
Method

Maximal Finger Force Capacity
• A specially designed platform
• Wall mounted
• 6D force sensor

Kinematics
• A camera (Basler A602fc, 100 Hz) in sagittal plane
• 4 reflective markers: lateral epicondyle, ulnar styloid process, distal and proximal end of middle finger metacarpal
Method

Test position

- Upright posture facing wall
- Parallel to hold plane
- Upper arm was positioned at 90° of flexion and 60° of abduction
- Elbow joint was flexed at approximately 90°
Method

Experimental procedure

1. Pulling the hold maximally in the vertical direction
2. Progressively increasing the forearm angle and transform the force direction from vertical to anterior-posterior
   Maximizing the anterior-posterior force

- Two trials per condition (4 depths x 3 grips) with 3 min resting periods
- Hold and grip sequences were randomized
Results

MFFC – vertical

- $350.8 \pm 56.0 \text{ N} \rightarrow 575.7 \pm 54.4 \text{ N}$ (49% -> 80% BW)
- No difference of MFFC between slope and half crimp
- Use of thumb significantly increase (20%) the MFFC on small (1-2 cm) holds
- On 3 cm hold, no MFFC difference between grip techniques
- On 4 cm hold, MFFC is higher for slope grip

Mean maximal vertical forces (N) with standard deviations according to the hold depth. Significant differences between grip techniques were shown (* $P<0.05$) for each hold depth.
Results

MFFC – vertical

- MFFC increased significantly between 1 and 2 cm holds for all grips
- Slope grip: MFFC increased significantly with hold depth
- Crimp grips: plateau points at 2 and 3 cm holds

Mean maximal vertical forces (N) with standard deviations according to the grip techniques. Significant differences between grip techniques were shown (* P<0.05) for each hold depth.
Results

MFFC – anterior-posterior

- 69.8 ± 20.0 N -> 138.0 ± 43.1 N (~10% -> 20% BW)
- Use of thumb significantly increase (40%) the MFFC on 1 cm hold
- MFFC increased significantly between 1 and 2 cm holds for all grips
- For all grip techniques, there is plateau point at 2 cm hold

Mean maximal anterior-posterior forces (N) with standard deviations according to the hold depth and grip techniques. Significant differences between grip techniques were shown (* P<0.05) for each hold depth.
Results

Kinematic

At the point of MFFC (ant-post)
• Wrist angle: $19.1^\circ \pm 14.6^\circ \rightarrow 51.6^\circ \pm 7.8^\circ$ extension

• Differed significantly according to the grip type and hold depth

• The difference is caused by the hand’s position
  ▪ slope grip: participants increased both the forearm and hand angles
  ▪ crimp grip: they preferred to keep the hand much more vertical
Results

Polynomial Fitting

Polynomials were fitted to the hold depth – vertical MFFC data for each grip technique.

Our estimations fit to Bourne et al. data well (4% avg error)

_It is possible to make an estimation model of maximal force capacity and hold depth._
Conclusion

• Differences in performance between grip techniques are more due to hold/finger interaction than biomechanical factors
• The slope grip allows climbers to increase the force progressively with increasing hold depth
• Crimp grips is better adapted for small holds
• When exerting ant-post forces, climbers have different hand-forearm posture strategies for open and crimp grips. This would be an advantage for the crimp grip as climbers have more possibility to adjust body posture with the fixed hand
• Our model of maximal finger force capacity vs. hold depth can be useful for
  ▪ hold manufacturers
  ▪ trainers
Thank you for your attention

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