# Fingerboard in Competitive Bouldering: Training Effects on Grip Strength and Endurance

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## Abstract

Medernach, JPJ, Kleinöder, H, Lötzerich, HHH. Fingerboard in competitive bouldering: Training effects on grip strength and endurance. *J Strength Cond Res* 29(8): 2286–2295, 2015—Bouldering (BL) is an independent discipline of sport climbing, with grip strength and endurance as key factors. Although the sport has grown increasingly popular and competitive, limited research has been conducted on commonly used training methods to maximize BL performance. The purpose of this study was to investigate the training effects of 4 weeks of fingerboarding (FB) on grip strength and endurance in competitive BL. Twenty-three highly advanced male boulderers (25.6 ± 4.4 y; 1.78 ± 0.05 m; 70.1 ± 5.4 kg; 6.2 ± 2.8 y climbing; 7b+ Fb mean ability) were randomly allocated to a 4-week FB ($n = 11$) or BL ($n = 12$) training regimen. Pretests and posttests (50-min duration) involved (a) handheld dynamometry (GS) to assess grip strength, (b) dead hangs (DH), and (c) intermittent finger hangs (IFH) to assess grip endurance. After the 4-week regimen, GS increased significantly in the FB group (2.5 ± 1.4 kg, $p < 0.001$) but not in the BL group (1.4 ± 2.8 kg, $p = 0.109$). The mean increase in DH ranged from 5.4 to 6.7 seconds in the FB group and was significantly ($p \leq 0.05$) higher than that in the BL group (3.0–3.9 seconds). Finally, significantly higher IFH gains were observed in the FB group ($p = 0.004$), with a mean gain of 26 seconds, but not in the BL group ($p = 0.168$). These results suggest that FB is highly effective in increasing grip strength and endurance in competitive BL.

**Key Words** hangboard, dead hangs, finger hangs

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## Introduction

Bouldering (BL) is an independent discipline of sport climbing undertaken without ropes on approximately 4-m-high artificial walls with landing mats to ensure safety (5,7,11,24). The ongoing popularization and professionalization of BL (5,9,17) have raised questions regarding how to maximize individual performance during competition (11,13). The use of steep overhanging artificial BL walls requiring an average of 4 to 8 strenuous climbing movements suggests that maximum grip strength is a key factor in competitive BL (5,7,9,11,13,24). Pieber et al. investigated injuries and overuse syndromes in the Austrian climbing society ($n = 193$) and observed that 71.1% of the 374 recorded injuries affected the upper extremities and that 30.7% were strains or ruptures of the annular ligaments or tendons of the fingers. Moreover, the authors concluded that the incidence of climbing-related overuse syndromes is dependent on gender, age, and exposure to climbing stress but is not specific to the climbing and BL disciplines.

In addition to grip strength, competitors generally require multiple attempts to climb a boulder (11,24), with attempts lasting up to 40 seconds (11,24), and the rotation system in competitive BL imposes limited recovery time between 2 boulders (7,24). White and Olsen found that successful ascents in elite competitive BL lasted an average of 39.5 ± 4.1 seconds and that athletes attempted a boulder 2.8 ± 1.7 times. In conclusion, high-intensity forearm muscle contractions, repeated over a relatively long period and separated by short rest periods, suggest that grip endurance can be considered an additional key factor and that rapid recovery after attempt is of particular importance in competitive BL (8,11,14,24).

Despite the increasing popularity and competitiveness of competitive BL, limited research has been conducted on this sport, and less is known regarding the effectiveness of commonly used training methods to increase grip strength and endurance (8,13,14,24). A similar level of knowledge can be observed over more than 2 decades in sport and rock climbing literature, in which scientific investigations of physical training and conditioning regimens still remain sparse (3,4,6,16,21,22). Results from sport climbing investigations, however, suggest that the trainable variables grip strength and grip endurance are of greater importance in increasing climbing ability compared with anthropometric or flexibility requirements (16,21). From this perspective, scientific research on applied grip strength and endurance exercises that maximize individual performance is essential for the future development of competitive BL.

A popular and widespread training device to increase grip strength and endurance in climbing and BL is the fingerboard (FB) (8,14,15). Fingerboards are equipped with a varying number of grips and are designed to be grasped without feet contacting the ground to ensure a high-intensity training stimulus that increases specific grip strength and endurance (8,14,15,23). As a training device for intermediate to world-class athletes (8,14), the main advantages of FB are the following: (a) low purchase prices, (b) low space requirements, (c) high access, (d) the possibility of isolated training programs with a wide variety of grip positions, and (e) the ability to design high-intensity programs at individual ability levels (8,14,15). Because of these characteristics, FB has become a conditio sine qua non for many competitive boulderers to increase grip strength and endurance (8,14).

However, from a scientific point of view, FBs have to date been used mainly as assessment tools to determine muscle strength and endurance (16,23); they have not been investigated as training devices to increase grip endurance in competitive BL. Thus, it remains unclear to what extent and in what time frame FB can contribute to increasing grip strength and endurance compared with conventional BL. This study, therefore, aimed to investigate the training effects of a 4-week FB regimen compared with a conventional BL regimen of equal duration and training volume. We hypothesized that FB would lead to greater gains in grip strength compared with BL because specific grip positions are worked maximally until muscle failure in FB (14). We also expected greater mean grip endurance gains in the FB group compared with the BL group because conventional BL involves low-height climbing routes with a limited number of climbing movements (7,14).

## Methods

### Experimental Approach to the Problem

To test our hypotheses, 23 highly advanced male boulderers were randomly allocated to a regimen of 4 weeks of FB ($n = 11$) or BL ($n = 12$), each consisting of 3 sessions per week with a duration of 150 minutes per session and a minimum rest period between 2 training sequences of 48 hours. Fingerboard and BL were determined to be independent variables. Pretests and posttests of 120 minutes in duration (dependent variables) involved the following: (a) grip strength assessed using handheld dynamometry (GS) and grip endurance determined as the hanging time to volitional fatigue, including (b) dead hangs in the common crimp, sloper, and pinch grips ($DH_{crimp}$, $DH_{sloper}$, and $DH_{pinch}$, respectively) and (c) intermittent finger hangs (IFH). In addition, body weight, room temperature, and perceived physical state (PEPS) were assessed to determine the potential influence of these variables on the test results.

The sport-specific tests used in this study to investigate grip strength and endurance were chosen to guarantee high test apparatus access and easily reproducible test criteria to promote the establishment of a database for future comparative data classification. Handheld dynamometry has been shown to be a valid and reliable method for assessing grip strength (1,19), and straight-arm isometric finger hangs until volitional exhaustion have previously been demonstrated by the intraclass correlation coefficient (ICC) to be a reliable indicator with a value that increases with climbing ability level (1,12). In addition, 6 subjects from this study were randomly selected from the FB and BL groups and performed a grip strength and endurance test-retest to assess reliability and consistency, separated by 48 hours of rest and with retest data serving as the initial pretest values.

### Subjects

A total of 23 highly advanced male boulderers volunteered to participate in the study and were randomly allocated using *abba* sorting to FB ($n = 11$) or BL ($n = 12$) regimens of equal duration and training volume. The FB and BL subjects had equal climbing abilities, comparable years of climbing experience, and similar body characteristics (Table 1). All participants (a) had to be at least 18 years old, (b) were recruited from local climbing clubs and commercial climbing centers, (c) had to be experienced in regular BL training in the past year (at least 1 training session per week), and (d) were not allowed to be engaged in a periodized training regimen in the last 4 weeks before the investigation to minimize the influence of past training effects on the investigation results. In addition, a self-reported BL ability of at least 7a Fb (Fb corresponds to Fontainebleau, a rating scale used in BL) in the 6 months before the investigation

**Table 1.** Subject characteristics by training samples.*†

| | FB ($n = 11$) | BL ($n = 12$) |
|---|---|---|
| Age (y) | 26.3 ± 4.5 | 25.0 ± 4.5 |
| Height (m) | 1.78 ± 0.04 | 1.77 ± 0.06 |
| Body mass (kg) | 71.0 ± 5 | 69.4 ± 5 |
| BMI ($kg \cdot m^{-2}$) | 22.4 ± 1.4 | 22.1 ± 1.2 |
| Climbing experience (y) | 5.8 ± 2.4 | 6.5 ± 3.2 |
| Climbing ability (au) | 9.8 ± 1.0 | 9.8 ± 0.7 |

*FB = fingerboard; BL = bouldering.
†Results are given as mean ± *SD*.

was required to ensure that the subjects had advanced BL ability. Reports from the FB-scale were converted to a climbing ability conversion table (2) to enable statistical analyses. Moreover, subjects had to complete a physical activity and health history questionnaire before participating in the study, and only healthy boulderers with no recent injuries and a minimum climbing experience of 3 years were recruited. All subjects verbally received testing instructions (sleep, nutrition, and hydration), provided written informed consent to participate in the study, and were informed of their right to leave the study at any stage. The study protocol received ethical approval from the German Sport University Cologne.

### Procedures

The investigation took place in-season (November to January) to minimize substantial temperature fluctuations and to avoid erroneous increases caused by lower physical states during the off-season. Pretests and posttest protocols, each with a 50-min duration, were performed at the same time of day (18:00 to 19:00) with a minimum rest period before data collection of 48 hours, during which no physical activity was allowed. The contents and timing of the pretests and posttests did not change and were the same for the FB and BL groups. Participants were supervised by the same examiner and were prompted to maintain their daily eating and sleeping habits. There was to be no alcohol consumption within 24 hours or caffeine consumption within 2 hours of data collection.

Participants arrived at 18:00 to the BL gym and began a sport-specific warm-up with 12–15 easy BL problems. After the warm-up, subjects were given multiple familiarization trials for GS, dead hangs (DH), and IFH. A standardized rest period of 7 minutes, during which body characteristics, PEPS, and room temperature were assessed, was implemented after warm-up. All grips were cleaned before data collection with a brush (Lapis, Ljubljana, Slovenia), and subjects were provided only White Gold Loose Chalk (Black Diamond, Salt Lake City, UT, USA) to ensure standardized grip conditions. For GS and DH, the highest score of 3 attempts and an exact recovery time of 5 minutes between attempts were ensured. A standardized rest time of 5 minutes was implemented because a recovery time of 3–5 minutes between 2 repetitions is recommended for high-intensity sport climbing exercises (8). Because hanging times during IFH were noticeably longer (approximately 74 seconds in pretest) compared with DH (approximately 5–6 seconds) and the maximum volitional contraction for GS, only 1 attempt was recorded for IFH to avoid an excessive test duration caused by the longer rest period required after hanging to volitional fatigue. For all tests, subjects were verbally encouraged until voluntary exhaustion. Hanging time to exhaustion for $DH_{crimp}$, $DH_{sloper}$, $DH_{pinch}$, and IFH was measured with a Sigma SC 6.12 stopwatch (Sigma, Rödermark, Germany) to an accuracy of 0.3 seconds.

*Body Characteristics, Room Temperature, and Perceived Physical State.* Subjects were weighed in shorts and t-shirts without shoes to the nearest 0.1 kg using a Seca 760 scale (Seca GmbH, Hamburg, Germany), and height was measured without shoes to the nearest 0.5 cm using a Seca 213 stadiometer (Seca GmbH). Because changes in temperature can affect hanging times to exhaustion (14), room temperature was investigated using a Lufft C200 thermometer (Lufft, Fellbach, Germany). The pretests and posttests included a valid 20-item PEPS questionnaire to assess individual perceived activation ($PEPS_{activation}$) and training ($PEPS_{training}$) states for both training groups and for the pretests and posttest (10).

*Handheld Dynamometry.* GS was assessed using a calibrated Smedley Spring dynamometer (Saehan; Gyeonggi-do, KR) in accordance with the recommendation of the American Society of Hand Therapists (19). Subjects sat on a Vario training bench (Kettler, Ense-Parsit, GER) with 90° flexion in the elbow joint, supination of the forearm such that the inside forearm was opposite the inside upper arm, and 0–30° dorsiflexion of the wrist. Moreover, applied maximal pressure occurred without the use of the thumb to enable sport-specific test implementation, the stretched hand was not allowed to touch any part of the body or the bench, and the grip span was adjusted to reach the phalanx distalis of the ring finger (Figure 1). Subjects had to perform 3 attempts with the dominant hand, gradually applying maximal pressure for 2 seconds. The highest score of the 3 attempts was recorded, with a standardized regeneration period of 5 minutes between attempts.

*Dead Hangs.* Dead hangs, which consist of isometric finger hangs to volitional fatigue, were assessed with a straight-arm position in the commonly used grip positions, such as (a) 19-mm crimp grip (Metolius Climbing, Bend, OR, USA), (b) Nr. 02 sloper grip (Skyroof, Geretsried, Germany), and

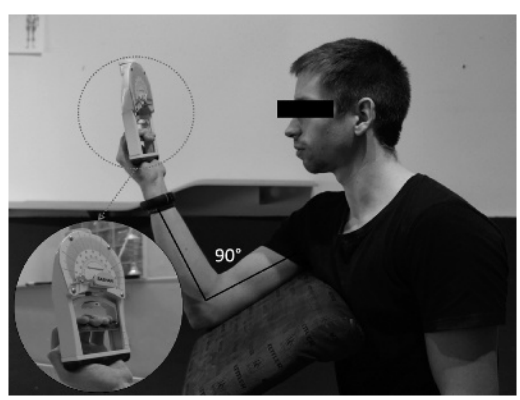


**Figure 1.** Handheld dynamometry to assess GS. The use of the thumb was not permitted to enable a sport-specific test implementation.

**Figure 2.** A 19 mm half crimp grip (Metolius Climbing) with the proximal interphalangeal joint flexed 90° or more and a hyperextended distal interphalangeal joint.

**Figure 4.** Nr. 01 pinch grip (Skyroof) with the thumb opposed to the fingers. The optical markers (black lines) guarantee a standardized gripping.

(c) Nr. 01 pinch grip (Skyroof), fixed at a vertical angle of 120° (Figures 2–4). Participants were instructed to maintain a straight-arm hanging position, which is a basic technique in climbing, and they had to hold that position for as long as possible. Exhaustion was defined as the participants' inability to continue hanging, despite verbal encouragement. In the pretest, subjects performed the DH with additional weight for maximal hang times ranging from 5 to 7 seconds. In the posttest after the 4-week training regimen, the corresponding pretest weight was used to assess the increase in hanging time to fatigue after 4 weeks. The highest score of the 3 attempts was recorded with a standardized rest time of 5 minutes between attempts. Hanging time to exhaustion was measured with a stopwatch with an accuracy of 0.3 seconds.

*Intermittent Finger Hangs.* Because climbing and BL require intense intermittent efforts from the forearm muscles (6,11,18,20), grip endurance was assessed by straight-arm IFH using a 30-mm deep crimp grip on the Alien fingerboard (Freestone, Saint Baldoph, France), fixed at 120° beyond vertical (Figure 5). A BL-specific hang-to-rest ratio of 8:4 seconds was chosen based on the study of White and Olsen, who found average hand contact times in competitive BL of approximately 8 seconds. Hanging time to fatigue was measured with an accuracy of 0.3 seconds using a stopwatch.

*Training Contents.* Subjects were supervised by qualified climbing coaches and performed individual warm-ups, which consisted of 12–15 easy BL problems and a short cool-down of 6–7 easy BL problems for each training

**Figure 3.** Nr. 02 sloper grip (Skyroof) with the proximal interphalangeal joint slightly flexed and the distal interphalangeal joint flexed from 50 to 70°.

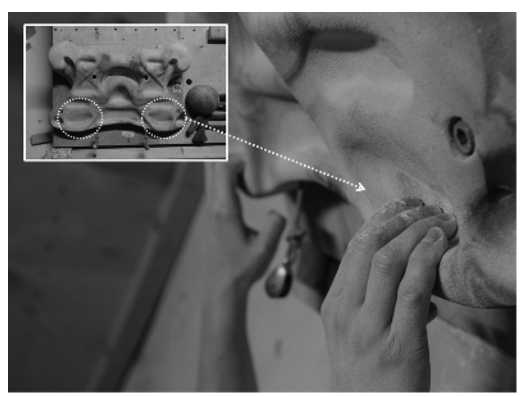

**Figure 5.** The fingerboard Alien (Freestone) fixed at 120° beyond vertical and equipped with the 30-mm edge depth crimp grip to assess hanging time to exhaustion during the intermittent finger hangs test.

**TABLE 2.** Detailed FB training regimen on the transgression FB (JM Climbing).*

| | Monday | Wednesday | Friday |
|---|---|---|---|
| Exercise | FB repeaters | FB hangs | FB repeaters |
| Description | Hang for 5 s<br>90° at the elbow joint | Hang for 3–5 s<br>Straight-arm position | Hang for 10 s<br>Straight-arm position |
| Total repetitions/sets | 6/5 | 10/3 | 8/5 |
| Rest between hangs (s) | 5 | 30 | 2 |
| Exercise | FB hangs | Frenchies | Lock-offs |
| Description | 8 s straight-arm position | Pull-up and 5 s locked off at top position; lower down; pull-up and 5 s locked off at 90°; lower down; pull-up and 5 s locked off at 120°, 2× pull-up | 5 s (straight-arm position) |
| | 8 s locked off at top position<br>8 s locked off at 120°<br>8 s locked off at 90° | | Lock-off right<br>Lower down<br>5 s (straight-arm position)<br>Lock-off left and lower down |
| Total repetitions/sets | 5/3 | 5/3 | 6/5 |
| Rest between hangs (s) | 10 | 30 | 0 |
| Exercise | Uneven lock-offs | FB hangs | FB pyramid |
| Description | 10 s right side<br>10 s left side | 20 s (straight arm)<br>2 pull-ups | 4 s (90° at elbow joint)<br>6 s (90° at elbow joint)<br>8 s (90° at elbow joint)<br>10 s (90° at elbow joint)<br>2 Pull-ups |
| Total repetitions/sets | 5/3 | 8/3 | 5/3 |
| Rest post repetition (s) | 10 | 10 | 10 |

*FB = fingerboard; BL = bouldering.

session. The FB training regimen is listed in Table 2. All exercises were chosen to be highly specific to competitive BL and were performed on the Transgression fingerboard (JM Climbing, Leezen, Germany). The Transgression fingerboard was chosen over the Alien fingerboard because it is equipped with 8 crimp grips with 6-, 7-, 8-, 9-, 10-, 12-, 14-, and 18-mm edge depths and an open-hand grip position, which enables individual-level training regimens without requiring additional weight during exercises (Figures 6 and 7). To best limit the risk of injuries, subjects (a) performed, in addition to the general warm-up, light hangs in the open-hand grip position of the FB, (b) avoided painful or stressful hold positions, (c) had to immediately stop the training at the first signs of pain in joints and tendons, (d) were instructed to perform a variety of exercises per session according to the prescribed training regimen, (e) performed all exercises in a controlled position, (f) chalked their fingers before all exercises to avoid slipping, and (e) observed a standardized rest time of 5 minutes between 2 exercises (8,13). In contrast, the CB group performed BL problems (25–35 attempts per training session) at individual ability levels with an average of 4–8 handholds per boulder, a BL time of less than 1 minute, and a complete recovery time after each set of 5 minutes. The FB and CB subjects were not allowed to perform any training regimens except those outlined in this section.

**Figure 7.** Open-hand grip position on the Transgression fingerboard (JM Climbing).

#### Statistical Analyses

Statistical analyses were performed using IBM SPSS Statistics 20 (IBM Corporation, Armonk, NY, USA) and Microsoft Excel 2007 (Microsoft Corporation, Redmond, WA, USA). All variables were assessed for normality of distribution using (a) a one-sample Kolmogorov-Smirnov test, (b) a skewness and kurtosis *z* value test, and (c) visual inspection of normal Q-Q plots. All study variables showed approximately normal distribution. Data are reported as mean values and standard deviations, and an alpha level of $p \leq 0.05$ (2-tailed) was used to determine statistical significance. Paired sample *t*-tests were used to determine the significance of the differences between the pretests and posttests, and multivariate analysis of variance (MANOVA) with Bonferroni's post hoc comparison was used to investigate the differences between the FB and BL groups. Intraclass correlation coefficients and paired sample *t*-tests were used to determine the reliability and consistency of grip strength and endurance tests in the test-retest format. The post hoc statistical power achieved was determined to be 0.5 for *t*-tests and 0.7 for the MANOVA.

**Figure 6.** The 8-mm edge depth crimp grip on the Transgression fingerboard (JM Climbing).

## Results

All 23 subjects successfully completed the 4-week investigation. Descriptive data on (a) body mass, (b) $PEPS_{activation}$, (c) $PEPS_{training}$, (d) room temperature, (e) GS, (f) $DH_{crimp}$, (g) $DH_{sloper}$, (h) $DH_{pinch}$, and (i) IFH are displayed in Table 3. Body weight did not change significantly between the pretests and posttests in both the FB ($t_{10} = -1.49$, $p = 0.167$) and BL ($t_{11} = 1.48$, $p = 0.166$) groups. In addition, no significant differences in body weight were found between the FB and BL groups in the pretests and posttests ($F_{[1,21]} = 0.49$, $p = 0.492$ and $F_{[1,21]} = 1.62$, $p = 0.217$, respectively). $PEPS_{activation}$ did not change significantly between the pretests and posttests in both the FB ($t_{10} = -0.84$, $p = 0.422$) and BL ($t_{11} = -1.03$, $p = 0.323$) groups. In addition, nonsignificant differences were found between the FB and BL groups in the pretests and posttests ($F_{[1,21]} = 0.48$, $p = 0.498$ and $F_{[1,21]} = 0.66$, $p = 0.424$, respectively). In contrast, a significantly higher $PEPS_{training}$ score was found after the 4-week regimen in both the FB ($t_{10} = -3.23$, $p = 0.011$) and BL ($t_{11} = -4.49$, $p = 0.001$) groups, with, however, nonsignificant differences between the groups in the pretests and posttests ($F_{[1,21]} = 4.01$, $p = 0.058$ and $F_{[1,21]} = 3.82$,

**Table 3.** Descriptive data on body mass, PEPS, room temperature, GS, DH, and IFH in pretests and posttests.*†

| Variable | FB (n = 11) Pre | FB (n = 11) Post | BL (n = 12) Pre | BL (n = 12) Post |
|---|---|---|---|---|
| Body mass (kg) | 71.0 ± 5 | 71.5 ± 5 | 69.4 ± 5 | 68.9 ± 4 |
| $PEPS_{activation}$ | 3.9 ± 0.6 | 4.1 ± 0.6 | 4.0 ± 0.6 | 4.3 ± 0.5 |
| $PEPS_{training}$ | 3.3 ± 0.9 | 4.1 ± 0.3‡ | 3.9 ± 0.4 | 4.4 ± 0.3‡ |
| Room temperature (° C) | 14.0 ± 0.4 | 13.6 ± 0.3‡ | 17.7 ± 0.4§ | 16.6 ± 0.5‡§ |
| GS (kg) | 50.2 ± 4 | 52.7 ± 4‡ | 53.3 ± 5 | 54.7 ± 5 |
| $DH_{crimp}$ (s) | 5.9 ± 0.4 | 12.5 ± 2.5‡ | 5.6 ± 0.5 | 8.6 ± 2.0‡§ |
| $DH_{sloper}$ (s) | 6.0 ± 0.7 | 11.4 ± 2.7‡ | 6.2 ± 0.6 | 9.2 ± 2.4‡§ |
| $DH_{pinch}$ (s) | 5.7 ± 0.5 | 12.4 ± 4.1‡ | 5.6 ± 0.5 | 9.5 ± 2.6‡§ |
| IFH (s) | 77.5 ± 23 | 103.7 ± 34‡ | 91.3 ± 29 | 92.4 ± 28§ |

*PEPS = perceived physical state; DH = dead hangs; IFH = intermittent finger hangs; FB = fingerboard; BL = bouldering.
†Results are given as mean ± *SD*.
‡Significant differences between pretests and posttests ($p \leq 0.05$).
§Significant differences between FB and BL ($p \leq 0.05$).

$p = 0.124$, respectively). Room temperature changed significantly between the pretests and posttests for both the FB ($t_{10} = 2.91, p = 0.016$) and BL ($t_{11} = 4.52, p = 0.001$) groups. Moreover, significantly lower room temperatures were found in the FB group compared with the BL group in both the pretests ($F_{[1,21]} = 517.9, p < 0.001$) and posttests ($F_{[1,21]} = 317.4, p < 0.001$).

Nonsignificant differences were found in GS (Figure 8) between the FB and BL groups in the pretests ($F_{[1,21]} = 2.69$, $p = 0.116$) and posttests ($F_{[1,21]} = 1.08, p = 0.310$), whereas a significant increase in GS after the 4-week regimen was observed in the FB group ($t_{10} = -6.17, p < 0.001$) but not in the BL group ($t_{11} = -1.75, p = 0.109$). No significant differences were observed in the pretest $DH_{crimp}$, $DH_{sloper}$, and $DH_{pinch}$ values (Figure 9) between the FB and BL groups ($F_{[1,21]} = 2.76, p = 0.111$, $F_{[1,21]} = 0.420, p = 0.524$, and $F_{[1,21]} = 0.08, p = 0.779$, respectively). However, significantly longer hanging times to exhaustion were found after 4 weeks in the FB group for $DH_{crimp}$ ($t_{10} = -8.87, p < 0.001$), $DH_{sloper}$ ($t_{10} = -7.83, p < 0.001$), and $DH_{pinch}$ ($t_{10} = -8.94, p < 0.001$) and in the BL group for $DH_{crimp}$ ($t_{11} = -5.05, p < 0.001$), $DH_{sloper}$ ($t_{11} = -4.51, p < 0.001$), and $DH_{pinch}$ ($t_{11} = -5.48, p < 0.001$). In addition, significantly higher times to exhaustion were found in the FB group compared with the BL group for $DH_{crimp}$ ($F_{[1,21]} = 13.94$, $p = 0.001$), $DH_{sloper}$ ($F_{[1,21]} = 5.86, p = 0.025$), and $DH_{pinch}$ ($F_{[1,21]} = 8.01, p = 0.010$). Finally, no significant differences in IFH times to exhaustion (Figure 10) were found between the FB and BL groups in the pretest ($F_{[1,21]} = 1.53, p = 0.229$). After 4 weeks of training, significantly higher IFH gains were observed in the FB

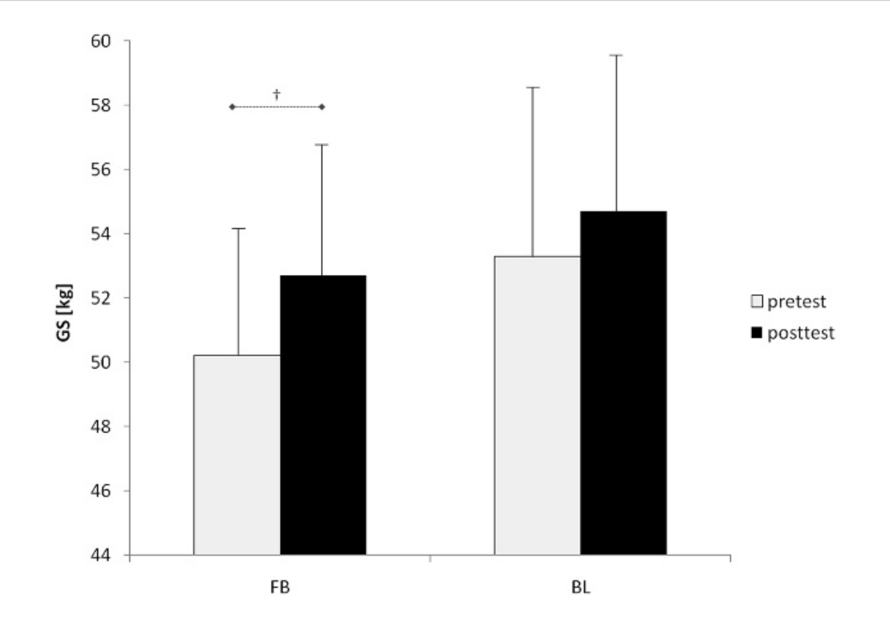


**Figure 8.** GS in pretests and posttests for the FB and BL groups, with a significant increase in GS after the 4-week regimen observed in the FB group (mean and *SD*). FB = fingerboard; BL = bouldering.

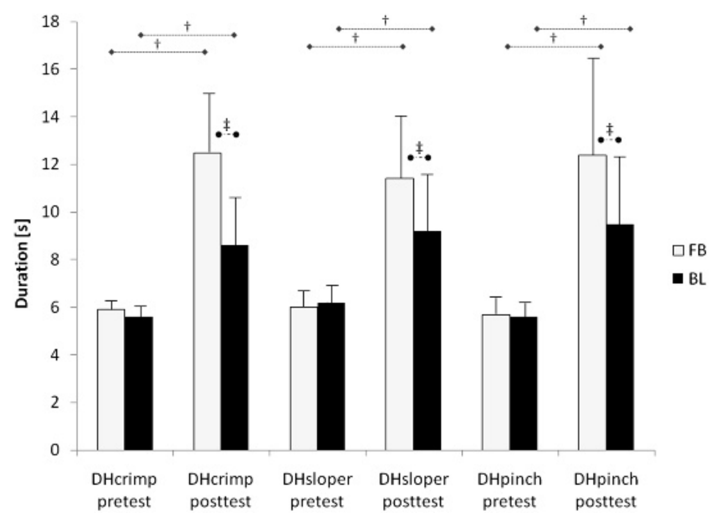


**Figure 9.** Mean dead hang increases after the 4-week training regimen for the FB and BL groups in crimp, sloper, and pinch grip (mean and *SD*). FB = fingerboard; BL = bouldering.

group ($t_{10} = -3.689$, $p = 0.004$) but not in the BL group ($t_{11} = -1.474$, $p = 0.168$). In addition, significantly higher increases were found after 4 weeks in the FB group compared with the BL group ($F_{[1,21]} = 12.55$, $p = 0.002$).

The test-retest results for reliability and consistency revealed nonsignificant differences in (a) GS ($t_5 = -0.79$, $p = 0.465$), (b) $DH_{crimp}$ ($t_5 = 0.099$, $p = 0.925$), (c) $DH_{sloper}$ ($t_5 = -0.386$, $p = 0.715$), (d) $DH_{pinch}$ ($t_5 = -0.215$, $p = 0.838$), and (e) IFH ($t_5 = -1.965$, $p = 0.107$). Test-retest ICCs (average measures) were estimated as follows: (a) 0.975 for GS (95% confidence interval [CI], 0.84–0.99), (b) 0.734 for $DH_{crimp}$ (95% CI, 0.36–0.96), (c) 0.844 for $DH_{sloper}$ (95% CI, 0.13–0.97), (d) 0.501 for $DH_{pinch}$ (95% CI, 0.04–0.94), and (e) 0.968 for IFH (95% CI, 0.36–0.96).

## Discussion

This study aimed to investigate the training effects of 4 weeks of FB on grip strength and endurance in highly advanced boulderers. To the best of our knowledge, this is the first study to investigate FB in competitive BL. The results of this study suggest that a 4-week FB regimen is a highly effective training method for increasing grip strength and endurance in competitive BL.

A major finding of this study is the significant increase in GS after the 4-week regimen for FB but not for BL. The descriptive data showed an increase in GS of 2.5 ± 1.4 kg in the FB group but only 1.4 ± 2.8 kg in the BL group. Different pretest reports of GS between FB and BL can be excluded as an explanation for these findings ($p = 0.116$). In contrast, according to Hörst, the lower mean gains in BL can be attributed to the numerous grip sizes and shapes in BL, such that the isolation of single grip positions cannot occur to the same extent as with FB. Maximum grip strength gains in climbing and BL, however, are to be expected when strength training occurs in a single grip position with maximal intensities to individual exhaustion (8). In addition, the reduced GS increase in the BL group can also be attributed to the fact that boulderers typically aim to find the most efficient strategy to solve a BL problem, whereas straight-arm finger hangs on the FB are implemented at maximum

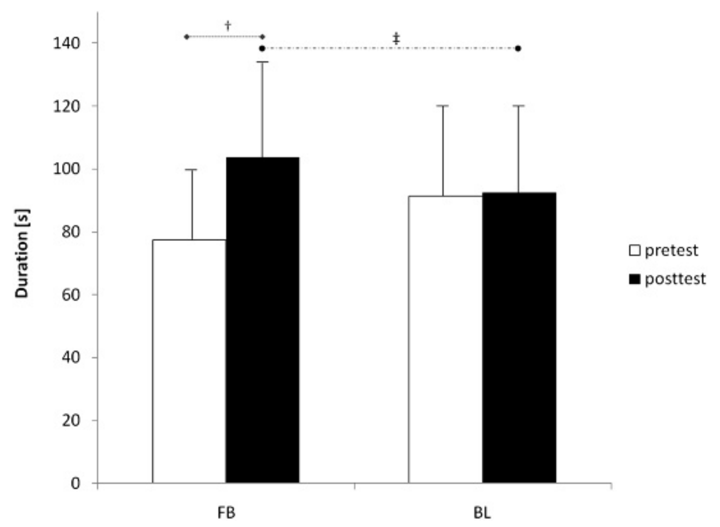


**Figure 10.** Mean intermittent finger hangs increases after the 4-week regimen for FB and BL (mean and *SD*). FB = fingerboard; BL = bouldering.

intensities to individual exhaustion (8,14), making gains occur much more rapidly in FB compared with BL. Moreover, highly skilled technical moves impede BL up to the point of muscle failure, which is, however, recommended for improving GS (8). These results confirm our hypothesis that FB leads to higher grip strength gains because specific grip positions are worked maximally until muscle failure (14). Although data from earlier scientific investigations are sparse, the present results suggest that FB for 4 weeks leads to GS increases in a relatively short period.

With respect to grip endurance, mean DH hanging times to exhaustion in the FB group after the 4-week investigation ranged from 5.4 to 6.7 seconds and were significantly higher than those achieved by the BL group (3.0–3.9 seconds). The results of this study were in accordance with those of Medernach who found that after a 4-week FB regimen, mean increases in hanging times to volitional fatigue of approximately 9 seconds. The slightly higher gains compared with those in this study may be attributable to the fact that Medernach's subjects were lead climbers with lower ability, which could have resulted in higher mean increases because grip endurance improvements occur more rapidly in less-skilled athletes compared with athletes with higher ability (8,14).

In addition, mean gains of approximately 26 seconds for IFH indicate that the muscle resistance regimen in FB serves as a highly effective training method for increasing grip endurance in competitive BL. The IFH results in this study confirm our hypothesis that FB leads to higher grip endurance gains compared with BL. The nonsignificant IFH increases in the BL group indicate that conventional BL is not an adequate grip endurance training method because of the limited number of climbing moves (7,14). When interpreting the grip endurance results, it should be taken into account that initial mean IFH times were substantially lower in the FB group (77.5 ± 23 seconds) compared with the BL group (91.3 ± 29 seconds), although these differences were not found to be significant. However, it remains unclear how advantageous these lower initial grip endurance values may be in increasing the ease of achieving grip endurance improvements in FB (8).

Although FB seems to be relatively stressful for the finger and elbows tendons (8,14) and the prescribed experimental design dictated an isolated 4-week FB regimen, none of the 11 subjects had to abandon the investigation because of acute complaints or injuries. Despite the high intensity of the exercises, our findings are in accordance with those of MacLeod and suggest that short-term FB in highly advanced boulderers is a relatively safe training regimen and that FB training is not per se associated with finger and elbow complaints. However, additional studies will be necessary to confirm this assumption and to investigate the potential consequences of long-term FB.

The subjects' height, body mass, and BMI scores were similar to those of (a) male boulderers of equal ability (5,13), (b) male lead climbers of equal ability (5), and (c) male aerobically trained nonclimbers (5,13). Nonsignificant differences in body weight between the pretests and posttests in both the FB and BL groups suggest that GS and endurance gains were not attributable to body weight decreases. Moreover, nonsignificant differences in $PEPS_{activation}$ scores between the pretests and posttests, as well as standardized framework conditions and test implementations, made external influencing factors rather improbable. However, the significantly ($p$ = 0.011 and $p = 0.001$) higher $PEPS_{training}$ scores for both the FB and BL groups on the posttest demonstrate that subjects estimated themselves to be in better training shape after the 4-week regimen. It therefore remains unclear to what extent psychological factors may have potentially caused variability in the results. In addition, room temperature changed significantly ($p = 0.016$ and $p = 0.001$) between the pretests and posttests for both the FB and BL groups, and a significantly lower room temperature was found for the FB group compared with the BL group in both the pretests and posttests ($p < 0.001$). However, it is very unlikely that room temperature influenced the hanging times to exhaustion in view of the minor observed differences between the pretests and posttests (0.4 and 1.1° C) and between the FB and BL groups (3.0 and 3.7° C).

Additional studies will be necessary to provide comparative data to facilitate interpretation of the mean GS and endurance gains in this study. In addition, the contributions of the reported GS and endurance increases to the enhanced performances during competitive BL remain unclear because GS and endurance are gained in isolation from BL (14). Because multiple variables, such as climbing skills, flexibility, and individual tactics, are required in high-performance competitive BL (8,14,22), future studies could investigate the relationship between observed GS and endurance increases and athletes' performance during competitive BL.

## Practical Applications

According to the main findings of this study, a 4-week FB training regimen is highly effective in increasing GS and endurance in competitive BL. The main advantages of FB are (a) low purchase prices, (b) low space requirements, (c) easy access, (d) isolated training with a wide variety of grip positions, and (e) highly intensive training stimuli at individual ability levels. However, FB is mentally exhausting because of the monotonous training pattern, and it remains a training supplement that is most effective when implemented in conjunction with the activity of BL (8,14). It is essential when performing grip strength and endurance exercises for competitive BL that the training exercises be performed in accordance with the specific requirements of competitive BL.

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