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Article

A Comparison of Upper Body Strength between Rock Climbing and Resistance Trained Men

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Abstract: Studies have shown that advanced rock climbers have greater upper body strength than that of novice climbers or non-climbers. The purpose of this study was to compare upper body strength between rock climbing and resistance trained men. Fifteen resistance trained men (age 25.28 ± 2.26 yrs; height 177.45 ± 4.08 cm; mass 85.17 ± 10.23 kg; body fat 10.13 ± 5.40%) and 15 rock climbing men (age 23.25 ± 2.23 yrs; height 175.57 ± 8.03 cm; mass 66.66 ± 9.40 kg; body fat 6.86 ± 3.82%) volunteered to participate. Rock climbing (RC) men had been climbing for at least two years, 2–3 times a week, able to climb at least a boulder rating of V4–5 and had no current injuries. Resistance trained (RT) men had been total body strength training for at least two years, 2–3 times a week with no current injuries. Each participant performed pull-ups to failure, grip strength, and pinch strength. RT were significantly older and heavier than RC. RC performed significantly more pull-ups (19.31 ± 4.31) than RT (15.64 ± 4.82). RC had greater relative pinch strength (R 0.27 ± 0.10 kg/kg; L 0.24 ± 0.07 kg/kg) than RT (R 0.19 ± 0.04 kg/kg; L 0.16 ± 0.05 kg/kg) and greater relative grip strength (R 0.70 ± 0.10 kg/kg; L 0.65 ± 0.12 kg/kg) than RT (R 0.57 ± 0.14 kg/kg; L 0.56 ± 0.15 kg/kg). Overall, RC men demonstrated greater performance in tests involving relative strength when compared to RT men. Rock climbing can promote increased upper body strength even in the absence of traditional resistance training.

Keywords: grip; finger; pinch; pull-ups; push-ups; relative

1. Introduction

Rock climbing involves lifting their body mass by pulling with their upper body musculature and using many different handholds and grips, including a wide 4-finger pinch and a small two finger pinch. This requires significant finger, grip and upper body strength. Balas [1] demonstrated that a higher climbing volume and an eight week training program resulted in increased grip and relative upper body strength of youth climbers. They also observed that hand-arm strength and endurance, body composition and climbing volume combined were predictors of climbing performance. Studies have also shown a significant difference in grip and pinch maximal voluntary contraction (MVC) in elite climbers when compared to recreational and non-climbers [2–6].

Predictors of climbing ability include upper body strength, grip and finger strength, along with high relative strength and lower body fat [7,8]. Elite climbers exhibit significantly greater strength than recreational climbers and non-climbers and this is seen even more prominent when the grip is more climbing specific [5,6,9]. Limonta *et al.* [2] observed a higher maximal voluntary contraction and a significant difference in endurance time between elite climbers and sedentary individuals during controlled fatiguing contractions in finger flexor muscles. Grant [4] determined that elite climbers had significantly greater flexibility (leg span), upper body strength (pull-ups and bent arm hang), and left and right pincer strength than recreational climbers and physically active non-climbers.

Based on the previous studies, rock climbing appears to have an important upper body strength component, which is derived from that training. Studies have observed significant differences in handgrip and pincer strength between climbers and sedentary individuals [3,4]. However, there is a paucity of research comparing strength of those involved in high-level rock climbing and traditional resistance training. Therefore, the purpose of this study was to compare upper body strength between rock climbers and resistance-trained men. We hypothesized that resistance trained men would exhibit significantly greater absolute grip due to their traditional training. Another hypothesis was that climbers would exhibit superior relative strength due to their experience with bodyweight support activity.

2. Materials and Methods

2.1. Participants

All participants were males between the ages of 20–29 with no injuries in the past six months that would prevent them from completing each task. Climbers had at least two years' experience, climbed indoors 2–3 times per week, outdoors at least once a month and did not participate in a structured resistance training program. Each participant was considered a self-reported "advanced" climber with at least a Hueco Scale rating of V4–5 (on a V0–16 scale) [10]. Resistance-trained men had at least two years' experience in full body lifting consisting of squats, deadlift, bench press and pull-ups. At the beginning of each visit, subjects signed a university IRB approved informed consent document. Then height and weight were recorded on a stadiometer (216, Seca Corporation, Ontario, CA, USA) and weight scale (ES200L, Ohaus Corporation, Pinebrook, NJ, USA).

2.2. Body Fat Percentage

Skinfold thickness was measured to the nearest .5mm using skinfold calipers (Lange, Santa Cruz, CA, USA). Two measurements were taken on the right side of the body (chest, abdomen and thigh) and the average of the values was recorded for analysis. Body fat percentage was estimated using the Jackson and Pollock equation [11].

2.3. Pull-Ups

For all performance tests, subjects performed at least three repetitions for warm-up and familiarization until they could execute the test per the specific guidelines, then rested for 2 min. Pull-ups and push-ups were counterbalanced. They completed the maximum number of pronated pull-ups possible in one minute [12]. They were positioned hanging from the bar with arms at full extension then pulled up so their chin reached the top of the bar then lowered themselves back down to full arm extension with their legs also fully extended [4]. If they used any momentum from their lower body as assistance the repetition was not counted. They were able to rest with arms at full extension, but if they let go of the bar the test was terminated.

2.4. Push-Ups

They laid prone on the floor and placed their thumbs at shoulder width, kept their body in a straight line and touched their chin to a tennis ball at the bottom of each repetition [13]. A cadence was set to 80 beats per minute (40 push-ups per minute) with a metronome and the test lasted a maximum of two min. When they were unable to keep the cadence or stopped due to fatigue, the test was terminated. [14].

2.5. Finger Strength

Participants rested for 5 min before finger strength tests were administered. A Flexiforce sensor (Model A201, South Boston, MA, USA) was used to measure finger strength between the thumb and all four fingers (1 = index, 2 = middle, 3 = ring, and 4 = little finger) [15]. They squeezed putty grip (Power putty) five times with each hand for warm-up, then rested 2 min. They were seated in an upright position with their arm placed on a table that was adjusted so that the elbow and shoulder joints were flexed to 90 degrees. Starting with the thumb and index finger, they placed the finger lightly over the sensor with the thumb opposed. The other fingers were curled under to prevent them from assisting when the sensor was squeezed. When signaled, they gradually squeezed the sensor for 5 s leading to maximal force. Next the thumb and middle finger were tested, with only the ring and little finger curled under. Then the ring finger was tested with only the little finger curled under. Finally, the little finger was tested last. Each finger on each hand was measured alternately three times with 15 s rest and the best of the three repetitions was recorded for analysis. Relative values were determined by dividing strength by body mass (kg/kg).

2.6. Pinch Strength

A handgrip dynamometer (T.K.K5401 Takei Koyo, Tokyo, Japan) was used to measure pinch strength. Participants squeezed putty grip (Power putty) five times with each hand for warm-up, then rested 2 min. The dynamometer was set to 4.5 cm wide [4]. They were seated in an upright position exactly the same as for finger strength with the dynamometer digital display facing away. They grasped the moveable arm of the dynamometer with four fingertips and the thumb opposed and braced around the immovable part of the device, while the administrator held the device stable [16]. Measurements were taken alternately between left and right hands with 15 s rest. Each hand was measured three times and the best of the three repetitions was recorded for analysis. Relative values were determined by dividing strength by body mass (kg/kg).

2.7. Grip Strength

The same handgrip dynamometer was used for measurement. The size of the grip was adjusted so that the second joint of the middle finger was positioned at 90 degrees. Participants were seated in an upright position on a box that was 47 cm tall, while holding the dynamometer in one hand, arm at their side with the digital display facing away. They squeezed the dynamometer for 5 s leading to maximal force then released [17]. Measurements were taken alternately between the left and right hands with 15 s rest. Each hand was measured three times and the best of the three repetitions was recorded for analysis. Relative values were determined by dividing strength by body mass (kg/kg).

2.8. Statistical Analyses

Two independent t-tests analyzed pull-ups and push-ups between groups. Multiple 2 × 2 (group × hand) mixed factor ANOVAs analyzed absolute and relative grip and absolute and relative pinch strength. Multiple 2 × 2 × 4 (group × hand × finger) mixed factor ANOVAs analyzed absolute and relative finger strength. Main effects were followed up with *t*-tests or LSD post hoc tests. Alpha level was set a-priori at 0.05.

3. Results

RT were significantly older and heavier than RC, but height and body fat percentage were not significantly different (Table 1).

Table 1. Mean ± SD of age, height, mass and body composition between resistance trained (RT) and rock climbing (RC) men.

Variable	RT	RC
Age (yrs)	25.28 ± 2.26*	23.25 ± 2.23
Height (cm)	177.45 ± 4.08	175.57 ± 8.03
Mass (kg)	85.17 ± 10.23*	66.66 ± 9.40
Body Fat (%)	10.13 ± 5.40	6.86 ± 3.82

Note: * Significantly (age $P = 0.02$; mass $P = 0.02$) greater than RC.

For pull-ups and push-ups, RC performed a significantly greater number of pull-ups than RT, but push-ups were not significantly different (Table 2).

Table 2. Mean ± SD of pull-ups and push-ups between resistance trained (RT) and rock climbing (RC) men.

Performance	RT	RC
Pull-ups (#)	15.64 ± 4.82	19.31 ± 4.31*
Push-ups (#)	38.28 ± 4.89	34.56 ± 8.13

Note: * Significantly (*P* = 0.03) greater than RT.

For absolute grip, there was no interaction or main effect for group but there was a main effect for hand with the right being stronger than the left. For relative grip, there was no interaction but there was a main effect for hand with the right being stronger than the left and a main effect for group with RC having significantly greater relative grip strength than RT (Table 3).

Table 3. Mean ± SD of left and right absolute and relative grip between resistance trained (RT) and rock climbing (RC) men and combined total for both groups.

Performance	RT	RC	Group Total
R grip (kg)	49.26 ± 14.16	46.15 ± 6.24	47.60 ± 10.61#
L grip (kg)	48.45 ± 15.42	43.16 ± 6.33	45.63 ± 11.60
R gripREL (kg/kg)	0.57 ± 0.14	0.70 ± 0.10	0.64 ± 0.14#
L gripREL (kg/kg)	0.56 ± 0.15	0.65 ± 0.12	0.61 ± 0.14
R&Lavg gripREL (kg/kg)	0.56 ± 0.14	0.67 ± 0.11*	-

Note: # Significantly (absolute *P* = 0.03; relative *P* = 0.01) greater than left; * Significantly (*P* = 0.02) greater than RT.

For absolute pinch, there was no interaction or main effect for group but there was a main effect for hand with the right being stronger than the left. For relative pinch, there was no interaction but there were main effects for group and hand. RC had significantly greater relative pinch strength than RT (Table 4).

Table 4. Mean ± SD of left and right absolute and relative pinch strength between resistance trained (RT) and rock climbing (RC) men and combined total for both groups.

Performance	RT	RC	Group Total
R pinch (kg)	16.07 ± 3.00	18.03 ± 7.01	17.11 ± 5.52#
L pinch (kg)	14.15 ± 4.65	16.11 ± 5.35	15.19 ± 5.05
R pinchREL (kg/kg)	0.19 ± 0.04	0.27 ± 0.10	0.23 ± 0.08#
L pinchREL (kg/kg)	0.16 ± 0.05	0.24 ± 0.07	0.20 ± 0.07
R&Lavg pinchREL (kg/kg)	0.18 ± 0.04	0.25 ± 0.08*	-

Note: # Significantly (absolute *P* = 0.00; relative *P* = 0.00) greater than left; * Significantly (*P* = 0.00) greater than RT.

For absolute and relative finger strength there were no significant three way or two-way interactions or main effects for group or hand. However, there was a main effect for fingers for both. Both absolute (Figure 1) and relative (Figure 2) finger strength were followed up with LSD post hoc tests for pairwise comparisons that showed the first finger was significantly stronger than fingers three and four. The second finger was significantly stronger than fingers one, three and four. The third finger was significantly stronger than finger four.

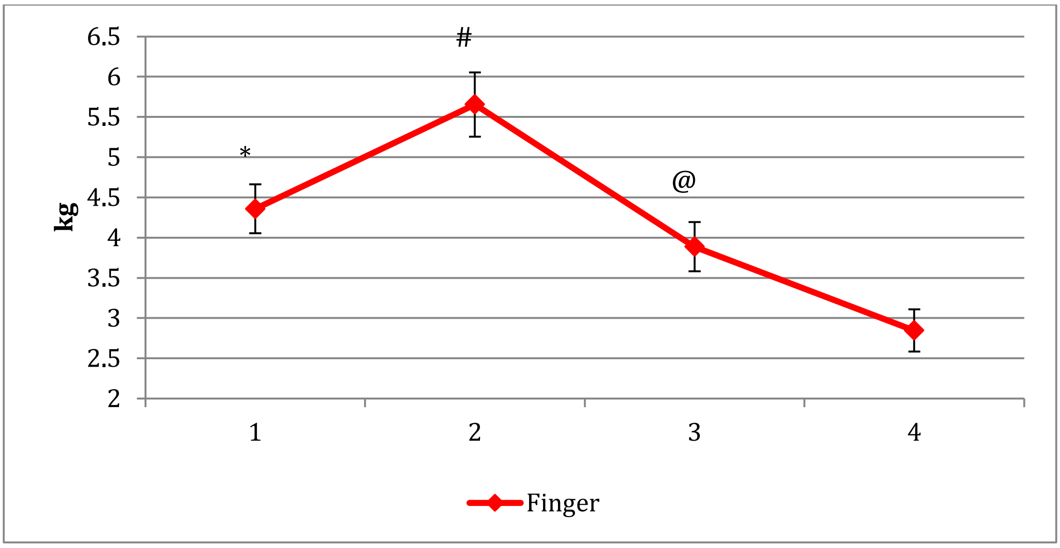

Figure 1. Mean ± SD of absolute finger strength. 1 = index, 2 = middle. 3 = ring and 4 = little. * Significantly (P = 0.00) greater than fingers 3 and 4; # Significantly (P = 0.00) greater than fingers 1,3 and 4; @ Significantly (P = 0.00) greater than finger 4.

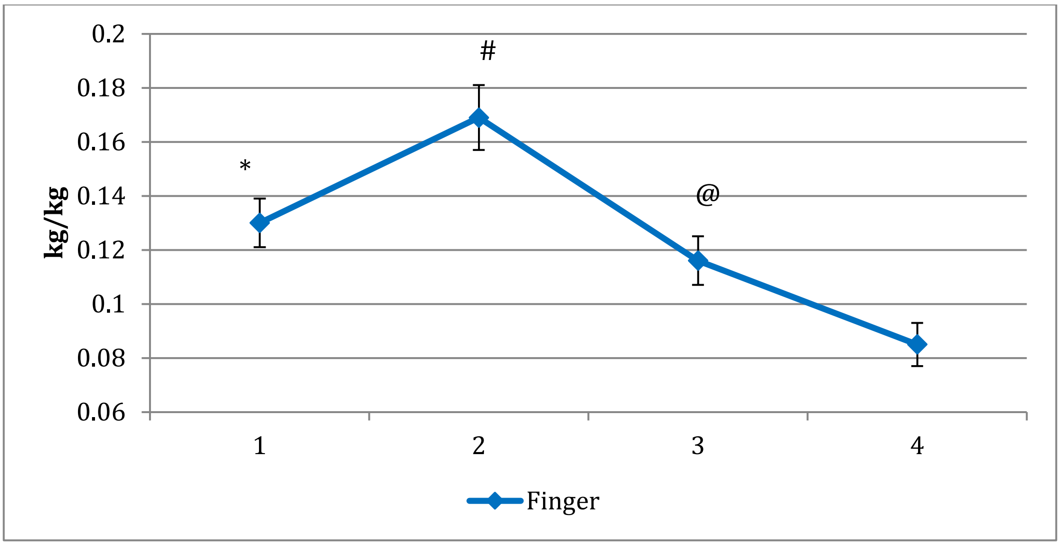

Figure 2. Mean ± SD of relative finger strength. 1 = index, 2 = middle. 3 = ring and 4 = little. * Significantly (P = 0.00) greater than fingers 3 and 4; # Significantly (P = 0.00) greater than fingers 1,3 and 4; @ Significantly (P = 0.00) greater than finger 4.

4. Discussion

The purpose of this study was to compare upper body strength between rock climbing and resistance trained men. The main findings were that rock climbers performed a significantly (P = 0.03) greater number of pull-ups, and had significantly greater relative grip (P = 0.01) and relative pinch (P = 0.00) strength than resistance trained men. This may be due to the physical demands required of rock climbing men to negotiate challenging routes successfully. These demands include lifting their body mass by pulling with their upper body musculature and supporting their body weight by many different handholds and grips [7,8]. Requirements for these demands include low body mass, strong pulling, pinching, and gripping strength to support body weight movements, and a large climbing volume in order to see increased relative strength and climbing ability [4,9,17]. In contrast, resistance trained men perform traditional weight room exercises and generally demonstrate greater absolute upper body strength but less relative strength than climbers. Grip strength of resistance trained men is developed through upper, and lower body exercises [18,19]. Climbers strengthen their upper body by lifting their own body mass and by directly working the grip via pinching and gripping [1,4,17]. Resistance trained men utilize exercises that indirectly strengthen their grip (*i.e.*, push-ups, squats, leg press, *etc.*) [18,19]. Therefore, it appears that both activities may be utilized to improve upper body strength.

In this study, we found that although groups were similar in height, climbers had significantly less body mass when compared to resistance trained men. This is probably due to the specific demands of each respective activity. Schweizer [20] determined that climbers had low levels of body mass and that body weight and height were negatively correlated with climbing performance. The current study corroborates that climbers' lower body mass probably led to greater relative strength.

In a contrasting study, Grant [4] demonstrated that there were no significant differences between elite, recreational and non-climbers for body mass, height, height:body mass ratio, or body fat %. It is important to note that they compared climbers to other climbers, not resistance trained men. So it is not known whether the elite climbers would have been significantly different in mass and body fat when compared to the resistance trained men of the current study. It is clear that low body fat and mass are desirable to climbers, however, there are numerous other variables that are used to determine climbing level such as type of training, climbing volume, grip, pinch, and finger strength [1,4,9,17]. For resistance trained men, training leads to hypertrophy and increased body mass which results in greater strength. This may be why resistance trained men in our study had significantly greater body mass. Despite differences in training, each group's goals overlap to some degree. Both desire increased upper body strength, which improves grip strength.

Balas [1] concluded that the practice of rock climbing resulted in increased upper body strength. He had young climbers, with little or no experience, participate in an 8-week climbing program and saw a significant increase in upper body strength, specifically, relative grip strength. In a similar study [17], he demonstrated that climbing volume and experience can predict performance, with a notable relationship between number of meters climbed per week, body fat, grip and bent- arm hang. Our results correspondingly showed that rock climbers had significantly greater relative pinch and grip strength. These two different grip types were chosen to be tested for the purpose of variation and specificity. The pinch is more climbing specific and the grip is more resistance training specific. It seems reasonable that if climbers utilized resistance training, focusing on larger lifts, it would result in improved upper body strength. However, a significant increase in mass might decrease climbing performance.

Several studies have shown that elite or advanced climbers demonstrate significantly greater MVC in a grip or pinch test [4,9,17,21]. Green [21] saw that trained climbers (similar to those in this study) had a significantly greater MVC and intermittent exercise capacity than untrained climbers. The conclusion is that climbing directly increases grip strength, similar to the current study.

Resistance training is commonly used to increase upper body strength. Thomas [18] observed the effects of a resistance training program on handgrip strength in young adults. Their results indicated that even though none of the movements in the training program involved specifically strengthening grip, each exercise contributed to overall improvement of absolute grip strength of the right hand only.

Another study by Wilmore [19] supports resistance training as a way to improve handgrip strength. Subjects participated in a training program that consisted of basic strength exercises and increased their absolute grip strength even though none of the exercises specifically strengthened handgrip. We hypothesized in the current study that resistance trained men would exhibit significantly greater absolute grip strength because absolute strength is the primary outcome of resistance training. However, we observed no difference between groups but climbers had significantly greater relative grip and pinch strength. Once again, this is probably due to climbers having less body mass.

Another hypothesis was that climbers would exhibit superior performance in tests of relative strength, such as push-ups and pull-ups. This was partially confirmed as climbers performed significantly more pull-ups than resistance trained men. Again, probably a result of climbers having significantly less body mass. Additionally, pull-ups are a very common movement performed in climbing and could lead to greater muscular endurance in rock climbers. Grant [4] also observed that elite climbers were able to perform significantly more pull-ups than recreational and non-climbers. In contrast, push-ups demonstrated no significant difference between groups. Push-ups were one of the exercises Balas [1] utilized in the resistance training program that indirectly improved grip strength. This suggests that push-ups could be part of a rock climbers training routine to aid in strengthening the upper body while also working the anterior chain in addition to the posterior chain, which is most often utilized while climbing. Resistance trained men are also at a slight disadvantage during push-ups as they must support greater overall body mass [13].

We did not find a significant difference in finger strength between groups. In contrast, Grant [4] found a significant difference in finger strength between elite and recreational climbers, but only for a climbing specific grip. The sensor used in the current study was very thin, making it less specific to a climbing grip and may not be a valid indicator of climbing finger strength. In addition, the resistance trained men were not familiar with the finger strength position.

Finally, Grant [9] compared climbing specific finger endurance in intermediate rock climbers, rowers, and aerobically trained men. This is the most similar study to ours comparing rock climbers to resistance trained men. Since the rowers followed a resistance training program it was thought that they would perform similarly to climbers. However, climbers demonstrated significantly greater MVC of a climbing specific grip when compared to rowers and aerobically trained men, but there was no difference between groups in endurance. These results further support that climbing directly improves grip strength.

5. Conclusions

Climbers demonstrated significantly greater relative grip and pinch strength and were also able to perform significantly more pull-ups than resistance trained men, due to their significantly lower body mass. Therefore, training for rock climbing should promote increased upper body strength in the absence of increased mass as relative strength appears to be an important parameter in this population. Additionally, testing rock climbers should focus on relative upper body strength as a positive indicator of performance.

Author Contributions

Kristina Macias, Lee Brown, Jared Coburn and David Chen were involved in study design, data collection, data interpretation, and manuscript writing.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Balas, J.; Strejcova, B.; Maly, T.; Mala, L.; Martin, A.J. Changes in upper body strength and body composition after 8 weeks indoor climbing in youth. *Isok. Exer. Sci.* **2009**, *17*, 173–179.
2. Limonta, E.; Ce, E.; Veicsteinas, A.; Esposito, F. Force control during fatiguing contractions in elite rock climbers. *Sport Sci. Health.* **2008**, *4*, 37–42.
3. Fanchini, M.; Violette, F.; Impellizzerim, F.M.; Maffiuletti, N.A. Differences in climbing-specific strength between boulder and lead rock climbers. *J. Strength Cond. Res.* **2013**, *27*, 310–314.
4. Grant, S.; Hynes, V.; Whittaker, A.; Aitchison, T. Anthropometric, strength, endurance, flexibility characteristics of elite and recreational climbers. *J. Sport Sci.* **1996**, *14*, 301–309.
5. Grant, S.; Hasler, T.; Dvies, C.; Aitchison, T.C.; Wilson, J.; Whittaker, A. A comparison of anthropometric, strength, endurance and flexibility characteristics of female elite and recreational climbers and non-climbers. *J. Sport Sci.* **2001**, *19*, 499–505.
6. MacLeod, D.; Sutherland, D.L.; Buntin, L.; Whitaker, A.; Aitchison, T.; Watt, I.; Bradley, J.; Grant, S. Physiological determinants of climbing-specific finger endurance and sport rock climbing performance. *J. Sports Sci.* **2006**, *25*, 1433–1443.
7. Schweizer, A.; Schneider, A.; Geohner, K. Dynamic eccentric-concentric strength training of the finger flexors to improve rock-climbing performance. *Isok. Exer. Sci.* **2007**, *15*, 131–136.
8. Mermier, C.M.; Janot, J.M.; Parker, D.L.; Swan, J.G. Physiological and anthropometric determinants of sport climbing performance. *Brit. J. Sports Med.* **2000**, *34*, 359–366.
9. Grant, S.; Shields, C.; Fitzpatrick, V.; Ming Loh, W.; Whitaker, A.; Watt, I.; Kay, J.W. Climbing-specific finger endurance: A comparative study of intermediate rock climbers, rowers, and aerobically trained individuals. *J. Sports Sci.* **2003**, *21*, 621–630.
10. Simon, B.; Draper, N.; Hodgson, C.; Blackwell, G. Development of a performance assessment tool for rock climbers. *Eur. J. Sport Sci.* **2009**, *9*, 159–167.
11. Jackson, A.S.; Pollock, M.L. Generalized equations for predicting body density of men. *Br. J. Nutr.* **1978**, *40*, 497–504.
12. Chen, K.W.; Chiu, P.K.; Lin, I.; Xu, K.F.; Hsu, M.; Liang, M.T. Study of basic military training of the physical fitness and physical self-concept for cadets. *J. Phys. Ed. Rec.* **2007**, *13*, 6–12.
13. Invergo, J.J.; Ball, T.E.; Looney, M. Relationship of push-ups and absolute muscular endurance to bench press strength. *J. Appl. Sport Sci. Res.* **1991**, *5*, 121–125.
14. Plowman, S.A. *Fitnessgram/Activitygram Reference Guide, 4th ed.*; Plowman, S.A., Meredith, M.D., Eds.; The Cooper Institute: Dallas, TX, USA, 2013.

15. Lee, S.; Kong, Y.; Lowe, B.; Song, S. Handle grip span for optimizing finger-specific force capability as a function of hand size. *Ergonomics* **2009**, *52*, 601–608.
16. Bacon, N.T.; Wingo, J.E.; Richardson, M.T.; Ryan, G.A.; Pangallo, T.C.; Bishop, P.A. Effect of two recovery methods on repeated closed-handed and open-handed weight assisted pull-ups. *J. Strength Cond. Res.* **2012**, *26*, 1348–1352.
17. Balas, J.; Pecha, O.; Martin, A.J.; Cochrane, D. Hand-arm strength and endurance as predictors of climbing performance. *Europ. J. Sport Sci.* **2011**, *12*, 16–25.
18. Thomas, E.M.; Shalber, M.; Svantesson, U. The effect of resistance training on handgrip strength and young adults. *Isok. Exer. Sci.* **2008**, *16*, 125–131.
19. Wilmore, J.H. Alterations in strength, body composition and anthropometric measurements consequent to a 10-week weight-training program. *Med. Sci. Sports Exer.* **1974**, *1*, 133–138.
20. Schweizer, A.; Furrer, M. Correlation of forearm strength and sport climbing performance. *Isok. Exer. Sci.* **2007**, *15*, 211–216.
21. Green, J.; Stannard, S. Active recovery strategies and handgrip performance in trained *vs.* untrained climbers. *J. Strength Cond. Res.* **2010**, *24*, 494–501.