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PHYSIOLOGICAL AND PSYCHOLOGICAL DIFFERENCES BETWEEN NOVICE AND ADVANCED BOULDERERS

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Gabriano E, et. al. Introduction: Rock climbing, especially bouldering, has increasingly become a mainstream sport. However, there has been little research comparing physiological and psychological traits of advanced and novice climbers. Methods: Thirty-two climbers (14 advanced (ADV), 18 novice (NOV) took part in this study. Anthropometric, body composition, flexibility, force, and psychological measurements were performed. MANOVA and post-hoc t-tests were used to compare between groups. Results: ADV climbed harder than NOV (V scale – 7.5 $\pm$ 1.6 vs 4.4 $\pm$ 1.2, $p < 0.05$). ADV were found to have significantly lower body fat percentage (12.3 $\pm$ 6.7 vs 17.5 $\pm$ 6.8%, $p < 0.05$), and higher grip strength relative to body weight (normal grip relative to body weight – 76.2 $\pm$ 14.1 vs. 63.1 $\pm$ 16.8% right hand, 74.7 ± 13.9 vs 58.9 ± 12.2% left hand, $p < 0.05$, Pinch grip relative to body weight – 0.4 $\pm$ .09 vs 0.3 $\pm$ .05%, $p < 0.05$), and maximum rate of force development as a percentage of body weight during a pull-up (.86 $\pm$ .38 vs .37 $\pm$ .30%, $p < 0.01$). Discussion: Advanced climbers have a significantly better power to weight ratio, giving them a better ability to generate explosive movements. It may be beneficial for novice climbers to train to increase their power to weight ratio, whether by increasing upper body power, decreasing fat mass, or increasing the grip to weight ratio.

Key Words: rock climbing, pinch grip, power to weight ratio

INTRODUCTION

With the introduction of rock climbing into the Summer Olympics in 2020 and its increasing popularity in the general population, rock climbing requires a greater examination to determine the factors that play a role in success. The three sub-disciplines within Olympic rock climbing, speed climbing, bouldering, and sport climbing, each require different skills and physiological traits. Previously, physiological traits such as anthropometrics, body composition, range of motion, and force capability (Mermier, Janot, Parker, & Swan, 2000; Michailov et al., 2018; Mitchell, Bowhay, & Pitts, 2011; Watts, Martin, & Durtschi, 1993) have been measured along with psychological traits such as self-efficacy (Gomez, Hill, & Ackerman, 2008) to differentiate between advanced and novice climbers. In addition, climbing experience is thought to be the major factor differentiating advanced and novice climbers (Mermier et al., 2000).

Anthropometrics such as height, forearm volumes, and ape index may affect a climber's economy and energy output by allowing for longer reaches. This results in decreased energy demands during climbing due to the use of fewer holds (Giles, Rhodes, & Taunton, 2006). However, anthropometric measurements have previously been found to explain less than 4% of the variance between skill levels of climbers, (Laffaye, Levernier, & Collin, 2016), suggesting that trainable aspects may play a bigger role in climbing success.

Decreased body fat and weight have been linked with elite climbing performance in both men and women, with World Cup sport-climbing finalists tending to be smaller in stature, though with minimal differences in body composition (Watts et al., 1993). However, other studies comparing elite men and women with recreational climbers found that both elite men and women tended to be slightly leaner than their recreational counterparts (Grant et al., 2001; Grant, Hynes, Whittaker, & Aitchison, 1996).

Range of motion or flexibility, especially in the hips and shoulders, have been suggested to be an important aspect of climbing due to the use of muscles in varying angles and/or contorted positions to be able to ascend a climbing route (Draper, Brent, Hodgson, & Blackwell, 2009). Previous studies have concluded that elite climbers have greater hip flexion and leg span than recreational climbers (Grant et al., 1996). In addition, shoulder and hip flexibility have been reported to be a predictor of performance, albeit weak (Mermier et al., 2000).

The ability to produce greater force and/or power by a climber may be beneficial to bouldering as many of the movements are characterized by short, powerful sequences (Laffaye, Collin, Levernier, & Padulo, 2014). One method of determining climbing specific power was using an "arm jump test" which involved performing an explosive pull-up and then ending by reaching as high as possible above the starting holds with both hands. This test was able to successfully differentiate between boulderers and route climbers and fairly accurately predict climbing ability (Laffaye et al., 2014).

Finally, the psychological make-up of individuals may also influence climbing ability. Grit, a measure of how much passion and perseverance one has in attaining a goal or objective (Duckworth, Peterson, Matthews, & Kelly, 2007), and resilience, the use of mental processes to protect against a potential negative effect of a stressor during a performance or to bounce back from an adverse event such as a fall (Fletcher & Sarkar, 2012; Galli & Gonzalez, 2015), may be increased in more advanced climbers and be associated with increased consistency and performance (Steinfort, 2015). In addition, better climbers have previously been reported to have higher self-efficacy, or confidence in their abilities, than weaker climbers (Gomez et al., 2008; Llewellyn, Sanchez, Asghar, & Jones, 2008).

Therefore, the purpose of this study was to examine experienced novice and advanced boulderers with similar years of experience and time spent climbing per week to determine what physiological and psychological differences may have caused the novice climbers to plateau in their ability. Because similar individuals were able to advance in climbing difficulty without spending more time climbing, it can be inferred that the novice climbers have plateaued for some reason. It was hypothesized that advanced boulderers would be more powerful, have lower body fat, be more flexible, and possess psychological characteristics more favorable to climbing success than their novice counterparts.

METHODS

Participants

All experimental procedures in this investigation were reviewed and approved by the Westmont College Institutional Review Board (IRB) prior to the beginning of this study. Participants were recruited by word of mouth in the local rock climbing gym. The protocols and procedures were explained, and all participants provided written informed consent prior to testing. Participants (N=32) consisted of experienced novice (n=18, males=11, females=7, experience = 5.6 $\pm$ 6.8 years, time spent climbing = 5.4 $\pm$ 3.7 hrs/wk, ability = V4.4 $\pm$ 1.2) and experienced advanced (n=14, males=7, females=7, experience = 5.2 $\pm$ 2.0 years, time spent climbing = 6.5 $\pm$ 3.1 hrs/wk, ability = V7.5 $\pm$ 1.6) boulderers. Participants had similar years of experience and time spent climbing per week. Participants were classified as novice if their hardest climb in the last 3 months was a V5 or easier and advanced if they had climbed a V6 or harder. Traditionally, V0 through V5 is considered beginner or intermediate climbing and V6 through V17 is considered advanced or expert climbing. Participants were excluded if they had any current musculoskeletal injury that would interfere with the testing procedures.

Procedures

Anthropometric Measures

The lengths of the right hand and forearm were measured to the nearest 0.1cm using a tape measure. Hand length was measured from the tip of the middle finger to the styloid process of the ulna. Forearm length was measured from the styloid process of the ulna to the olecranon process. In addition, arm span was measured as the distance from the middle finger on the right hand to the middle finger on the left hand with arms outstretched and parallel to the ground at shoulder height. Hand and forearm volume was measured through submersion, which allowed for the calculation of muscle and fat content (Maughan, Watson, & Weir, 1984). In short, the hand was submerged to the styloid process and water displacement was measured when the water stabilized. Next, the forearm was submerged to the level of the olecranon process and water displacement was measured after the water stabilized.

Skinfold thickness was measured to the nearest 1.0mm at seven sites using a Lange Caliper. The sum of the seven skinfolds (SSF) was recorded and body density was estimated according to the generalized equations for men and women with the Jackson and Pollack equations (Jackson & Pollock, 1985). Percent body fat (%fat) was estimated via the Siri equation (Siri, 1961).

Participants used a hand grip dynamometer to produce hand grip strength and pinch grip strength measurements (Lafayette Instruments, Lafayette, Indiana, United States). Hand grip was measured as the average of three different trials. Maximum hand grip force was determined as the highest of three trials. The participants were asked to adjust the handle to a comfortable width and were encouraged to give maximal effort. For the pinch grip test, participants were asked to hold the handle between the thumb and the forefingers, using only the 2nd through 4th fingers (Figure 1). Participants were asked to squeeze the dynamometer with maximal effort. For the hand grip and pinch grip tests, participants rested for a minimum of 30-60 seconds between trials. Measurements were taken to the nearest 0.5kg. Participants were not asked for their preferred dominant hand, so measurements were taken with both the right and left hand. Because the majority of the population is right-handed, we primarily used the right hand for calculations.

Figure 1. *Pinch grip measurement*

Flexibility

Hip flexibility in the right leg was measured by active and passive hip flexion and hip abduction. First, active and passive hip flexion was measured with participants in a supine position on a hard table. A goniometer was placed on the greater trochanter of the hip and the participant was instructed to bend at the hip and knee, actively bringing the knee as close to the chest as possible (Grant et al., 1996). Active hip flexion was measured as the greatest hip angle that could be actively held with the quadriceps muscle. The participant was then asked to use their arm to pull the knee closer to the chest, passively flexing the hip. Passive hip flexion was measured as the greatest hip angle that could be passively attained. Next, hip abduction was measured in a supine position. A goniometer was placed on the inguinal fold of the leg at the axis of rotation. The participant was asked to abduct their leg as far as possible. Hip abduction was measured as the greatest degree of abduction.

Shoulder flexibility in the right arm was measured by shoulder flexion, abduction, and adduction. First, shoulder flexion was measured as the participant was instructed to flex their arm from anatomical position. The goniometer was placed over the glenohumeral joint. The shoulder flexion range of motion was determined as the degrees through which the arm moved from anatomical position. Second, shoulder abduction was measured. The participant was asked to place their arm straight in front of them, parallel to the ground. They were then asked to move their arm to the side through the frontal plane until they were unable to move further. Shoulder abduction range of motion was measured as the degrees through which the arm moved from the starting position at the glenohumeral joint. Third, shoulder adduction was measured. From the same starting point as shoulder abduction, the participant was asked to move their arm across their body in the frontal plane. Shoulder adduction range of motion was measured as the degrees through which the arm moved from the starting position.

Finally, two climbing specific flexibility tests were measured in both legs. The Grant foot raise simulates the high step maneuver often performed while climbing. Participants were asked to stand on a line 23cm from the wall, with both hands placed on the wall at shoulder height. The participant was then asked to place their toe on the wall as high as possible without allowing it to move laterally. The distance from the floor to the bottom of the toe was recorded to the nearest 0.5cm (Grant et al., 1996). The second test was measured to simulate the bridging movement often performed while climbing. Participants were asked to lay supine on the ground with both legs raised on the wall. The participant was asked to abduct both legs as far as possible while keeping their glutes and legs pressed against the wall with knees straight. Leg span was measured from the medial calcaneus of one foot to the medial calcaneus of the other foot. One measurement was taken to the nearest 0.5cm using a tape measure.

Upper-Limb Power Test

During the upper-limb power test, participants were asked to dead-hang with straight arms from two small holds that were approximately 2-3cm deep with a slight lip. Each hold was attached to a separate board, positioned approximately 45-50cm apart, that could freely slide in a bracket that was attached to a vertical wall. The bracket extended from the wall 3.5cm. A force transducer (MLP-300; Transducer Techniques, Rio Nedo Temecula, CA) was attached to the board with an inelastic strap, allowing the force that the participant exerted on the hold to be measured with the force transducer (Figure 2).

The participant was asked to grasp two holds, each with one hand, using an open-handed slope grip (Amca, Vigouroux, Aritan, & Berton, 2012) and hang for three seconds to establish a baseline force due to the force of gravity on the weight of the participant. After three seconds, the participant was asked to perform an explosive pull-up movement, as if they were trying to reach a high hold above their head. They were asked to repeat this movement two times, resting for at least one minute between pull-ups.

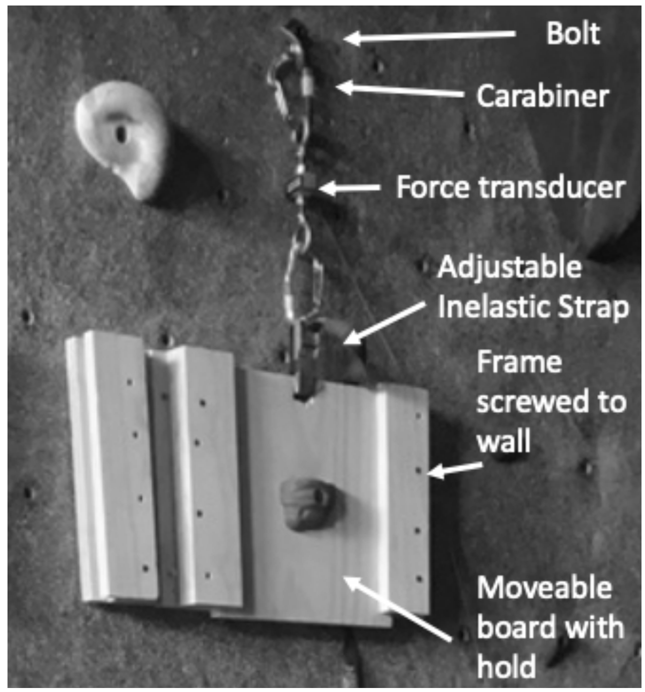

Figure 2. *Force measurement system and experimental setup. The hold was mounted on a board that was placed between two frames that allowed the board to freely slide. The board was then attached to an inelastic strap which was connected to a force transducer. The force transducer was clipped to a bolt by a carabiner to mount the hold to the wall.*

The baseline hanging force and peak force were recorded by a Biopac MP35 (BIOPAC Systems INC., Goleta, CA, USA). The peak force was measured as the highest force recorded during the explosive pull-up movement (pull-up force). Maximum rate of force development (MRFD) was measured as the time from the beginning of the contraction to the peak force in N/s (pull-up power). Peak force is an absolute measurement, whereas maximum rate of force development introduces time to the equation and allows for a measurement of power. Both maximal force and power were then divided by body weight to normalize between the participants.

Psychological Tests

Each participant was asked to complete five psychological surveys, each relating to a potential component of the mental make-up necessary for climbing success. The 8-item GRIT-S survey was used to determine trait-level perseverance and passion for long-term goals (Duckworth & Quinn, 2009) using two, four item subscales. Each participant was asked to answer the following statements honestly on a five-point Likert-Type scale (1-*not at all like* me to 5-*very much like* me). Examples of items included "I have difficulty maintaining my focus on projects that take more than a few months to take" (interest subscale) and "Setbacks don't discourage me" (effort subscale). Scores were summed for each subscale and ranged from 4-20 with higher totals indicating more interest or effort. Cronbach's alpha for the interest subscale was 0.834 and effort subscale was 0.762.

The 10-item Connor Davidson Resilience Scale (CD-Risc) survey was used to determine resilience characteristics in participants (Galli & Gonzalez, 2015). Participants were directed to indicate how much they agreed with statements as they apply to their lives. Each item was responded to on a five-point Likert-Type Scale (0-*not at all true* to 4-*true nearly all the time*). Example items included "I can deal with whatever comes my way," "Having to cope with stress can make me stronger," and "I tend to bounce back after illness, injury, or other hardships." Scores were summed and ranged from 0-40 with higher totals indicating more resilient characteristics. Cronbach's alpha for the CD-Risc in this study was 0.835.

The 5 Factor Mindfulness Questionnaire was used to assess mindfulness capabilities in the participants (Baer, Smith, Hopkins, Krietemeyer, & Toney, 2006). The five factors include: 1) observing, 2) describing, 3) acting with awareness, 4) non-judging of inner experience, and 5) non-reactivity to inner experience. Each participant was asked to rate the provided statements with a five-point Likert-Type Scale (1- *never or very rarely true* to 5- *very often or always true*). Examples of items for each of the subscales include "When I'm walking, I deliberately notice the sensations of my body moving" (observing), "I'm good at finding words to describe my feelings" (describe), "When I do things, my mind wanders off and I'm easily distracted" (acting with awareness), "I tell myself I shouldn't be feeling the way I'm feeling" (non-judging of inner experience), and "When I have distressing thoughts or images, I "step back" and am aware of the thought or image without getting taken over by it" (non-reactivity to inner experience). Scores were summed for each subscale and ranged from 8-40 with higher scores indicating higher abilities on the five factors. Cronbach's alphas for the scales ranged from 0.712 to 0.930.

The 10-item General Self-Efficacy Scale (GSES) was used to examine the coping ability of individuals (Schwarzer & Jerusalem, 1995). Each participant was asked to respond to 10 questions using a four-point Likert-Type Scale (1-*not true at all* to 4-*exactly true*). Examples of questions include "I can always manage to solve difficult problems if I try hard enough" and "I can remain calm when facing difficulties because I can rely on my coping abilities." Scores were summed for each question and ranged from 10-40 with higher scores indicating an increased coping ability. Cronbach's alpha for the scale was 0.789.

The 10-item climbing specific self-efficacy scale (CSES) was used to examine self-efficacy specific to climbing (Llewellyn et al., 2008). Each participant was asked to respond to 10 questions, rating each question out of 100. The following anchors were used to help participants rate the questions, 0-*not confident*, 50-*moderately confident*, 100-*extremely confident*. Examples of questions include "My confidence in my ability to prepare mentally for challenging routes", "My confidence in my ability to prepare physically for demanding routes", and "My confidence in my ability to manage my fears and anxiety". Scores were summed for each question and ranged from 0-1000 with higher scores increasing increased climbing self-efficacy and confidence. Cronbach's alpha for the scale was 0.834.

Statistical Analysis

All analyses were performed using the SPSS program (version 19, Chicago, IL) and Microsoft Excel

(Microsoft version 16.9, Redmond, WA) software packages. The data are reported as means and standard deviations. Variables were grouped by category and analyzed using a multivariate analysis of variance (MANOVA) with independent t-test post-hoc analysis. Statistical significance was set at $p \leq 0.05$.

RESULTS

Group Characteristics

There was a significant difference in age ($p < 0.05$) and bouldering ability ($p < 0.05$), but not in height or weight (Table 1). There was also not a difference in years of climbing experience as the advanced had been climbing for 5.2±2.0 years versus 5.6±6.8 years for the novice. There were also no differences in the average days of climbing or hours per session for advanced or novice for the last three months.

Anthropometrics

There was no difference in anthropometric data between novice and advanced ($F(6,25) = .534$, $p > 0.05$). Right arm length, right hand length, arm span, and ape index did not differ between the groups ($p > 0.05$) (Table 1).

Table 1. *Mean ± SD physical characteristics for advanced and novice.*

	Novice (n = 18)		*Advanced (n=14)*	
	Mean	*SD*	*Mean*	*SD*
Age (years)	28.9	10.1	22.7*	3.2
Weight (kg)	69.3	9.8	62.0	16.4
Height (m)	1.74	10.9	1.71	8.7
Ability (V scale)	4.4	1.2	7.5	1.6
Climbing Experience (years)	5.6	6.8	5.2	2.0
Time Climbing/wk (hours)	5.4	3.7	6.5	3.1
Body Fat (%)	17.5	22.3	12.3*	18.5
Forearm Length (cm)	26.5	2.3	25.9	2.1
Hand Length (cm)	17.9	3.1	18.1	1.3
Arm Span (cm)	176.3	11.5	174.0	10.6
Ape Index (m)	2.8	5.0	2.86	4.1

* Significant different from novice (p < 0.05)

Body Composition

Body composition differed between novice and advanced ($F(3,28) = 4.474$, $p < 0.05$). While weight did not differ between novice (69.3 ± 16.4kg) and advanced (62.0 ± 9.8kg, $p > 0.05$), advanced were significantly leaner than novice (12.3 ± 6.7% vs 17.5 ± 6.8% body fat, $p < 0.05$, Table 1). However, forearm fat percentage did not differ between advanced and novice climbers ($p > 0.05$).

Flexibility

Flexibility was broken down into three sub-components, hip flexibility, shoulder flexibility, and climbing specific flexibility. Hip flexibility was not significantly different between groups ($F(3,27) = 1.752$, $p > 0.05$), though active hip flexion was significantly greater in advanced (123.1 ± 16.4°) than novice (111.5 ± 12.3°, $p < 0.05$) though there was no difference in passive hip flexion ($p > 0.05$, Figure 3). Hip abduction approached significance with advanced being more flexible ($p = 0.065$). Shoulder flexibility did not differ between groups ($F(3,28) = 1.125$, $p > 0.05$), nor were there any differences in the sub-components of shoulder flexibility. There were also no differences in climbing specific flexibility between groups ($F(2,29) = .193$, $p > 0.05$). Novice were able to raise their foot 2.2cm higher than advanced ($p > 0.05$, Figure 3) though advanced were able to span 4cm more ($p > 0.05$, Figure 3).

Grip Strength

The grip strength category was broken down into two components, normal grip strength and pinch strength, for both the right and left hand. Grip strength as a whole did not differ between groups ($F(4,27) = .962$, $p > 0.05$). Normal grip strength for the right hand and left hand was not different between groups ($p > 0.05$, Figure 4) nor was pinch strength different for the right or left hand ($p > 0.05$). However, grip strength as a percentage of body weight was significantly different between groups ($F(4,27) = 4.154$, $p < 0.01$, Figure 4). With a normal grip, advanced were able to grip a greater percentage of their body weight with both hands than novice ($p < 0.01$ for both). For the pinch grip, advanced were also able to grip more than novice with their right hand ($p < 0.01$) and their left hand ($p < 0.05$).

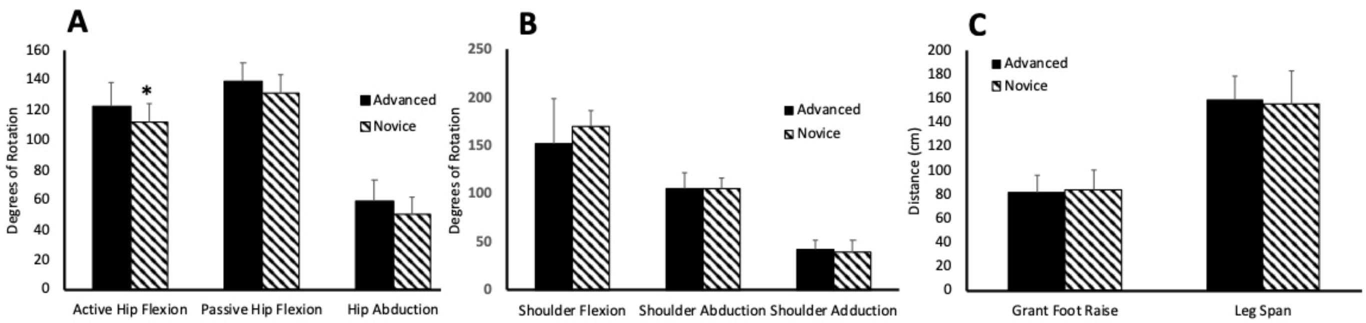

Figure 3. *Mean ± SD flexibility measurements for advanced and novice for hip (A), shoulder (B), and climbing specific (C) flexibility measures. Significant differences between flexibility tests are shown (* p < 0.05).*

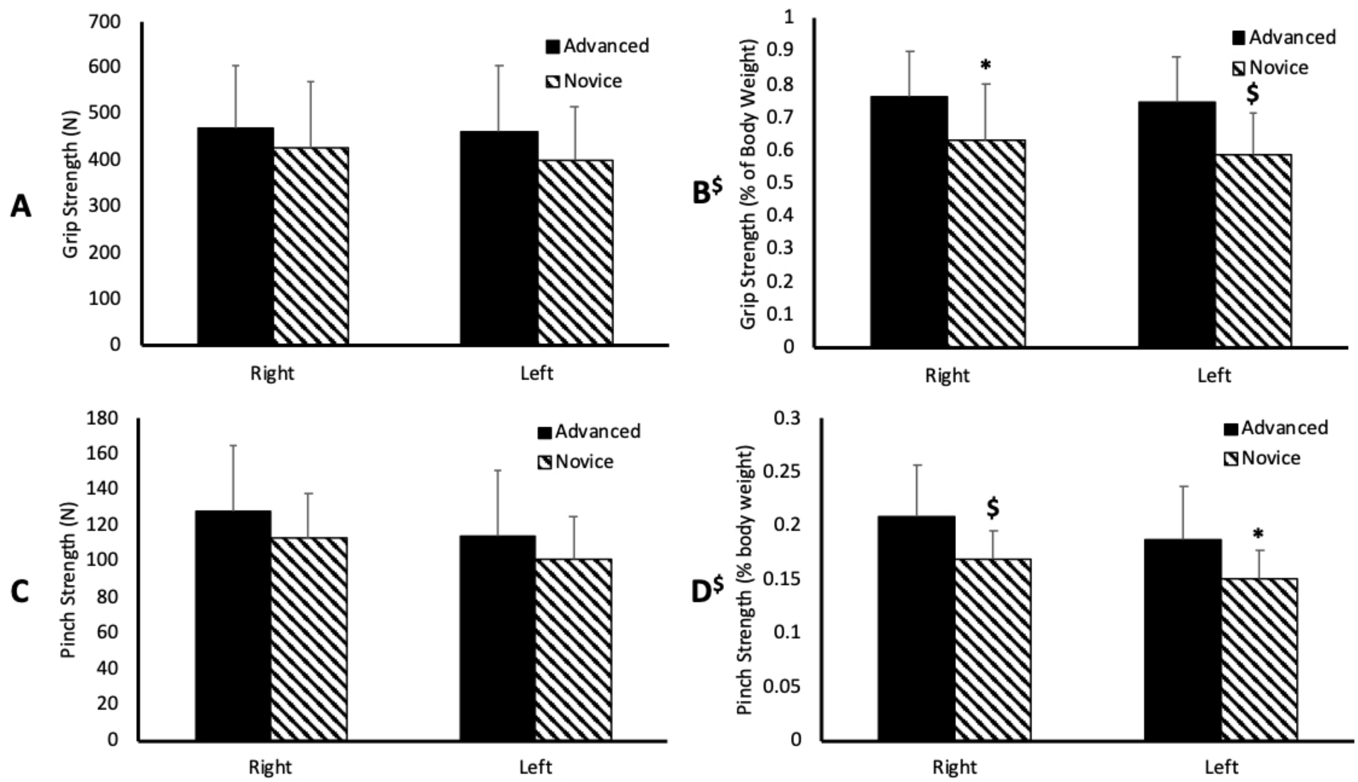

Figure 4. *Mean ± SD grip strength (A), grip strength normalized for body weight (B), pinch strength (C), and pinch strength normalized for body weight (D) measurements for advanced and novice. Significant differences for grip strength tests are shown (* $p < 0.05$, $^{\$}$ $p < 0.01$, $^{\&}$ $p < 0.001$).*

Upper body force

Peak pull-up power as determined by the maximal force attained by the climber after a three second hanging baseline did not differ between advanced and novice ($F(2,24) = .250$, $p > 0.05$) with either hand ($p > 0.05$) as shown in Figure 5. Even when corrected for body weight, there was no difference in force per body weight that was exerted ($F(2,25) = .911$, $p > 0.05$) either for right hand as a percentage of body weight ($p > 0.05$) or for the left hand ($p > 0.05$). However, when the maximal rate of force development (MRFD) was examined, there was a significant difference as advanced were able to generate force much more quickly than novice ($F(2,24) = 7.416$, $p < 0.01$, Figure 5). For both hands, advanced were able to generate more than twice as much power ($p < 0.05$) as novice ($p < 0.05$ right hand, $p < 0.001$ left hand). When MRFD was normalized for body weight, there was a significant difference between advanced and novice ($F(2,23) = 9.346$, $p < 0.001$), with the right hand generating 2.6x ($p < 0.01$) more normalized power and the left hand generating 2.3x ($p < 0.001$) more normalized power in advanced (Figure 5).

Psychological Questionnaires

There were no psychological differences between the groups when all of the measures were grouped ($F(5,23) = .685$, $p < 0.05$). There were no differences in Grit between the advanced and novice, nor for the subscales of grit (Table 2). Advanced trended towards having more resilience (30.7 ± 4.4) than novice (28.3 ± 4.8, $p = 0.15$). There were also no differences in mindfulness between groups ($p > 0.05$). There were no differences in general efficacy nor were there differences in climbing efficacy, though advanced trended towards having greater climbing efficacy than novice ($p = 0.14$).

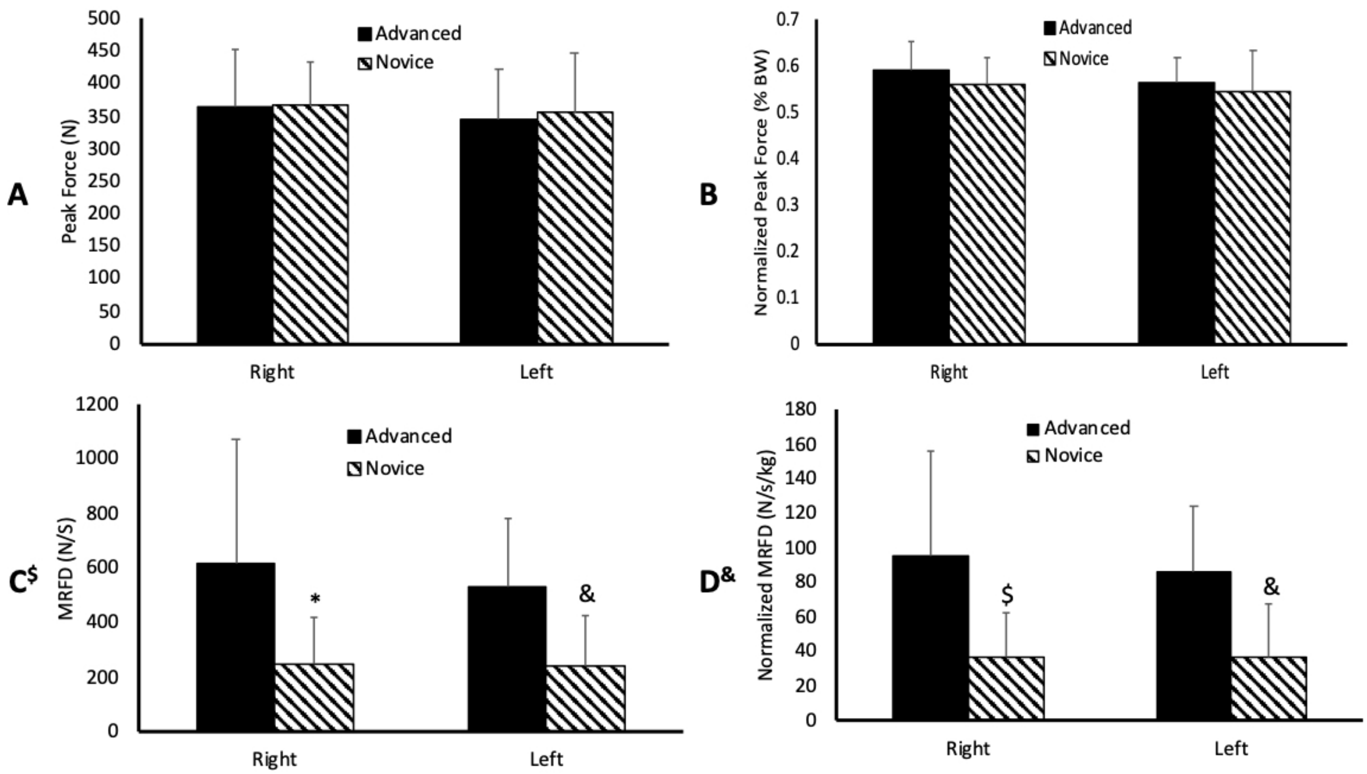

Figure 5. *Mean ± SD peak force (A), normalized peak force (B), maximum rate of force development (C), and normalized maximum rate of force development (D) for advanced and novice. Significant differences for grip strength tests are shown (* p < 0.05, $ p < 0.01, & p < 0.001).*

Table 2. *Mean ± SD psychological measures for advanced and novice climbers. There were no differences between groups.*

	Grit			Resilience	General Efficacy	Climbing Efficacy
	Total	Consistency of Interest	Perseverance of effort	Total	Total	Total
Advanced	29.5 ± 6.2	13.3 ± 3.6	16.2 ± 3.1	30.7 ± 4.4	33.9 ± 2.4	790 ± 84.5
Novice	29.1 ± 5.2	13.4 ± 2.8	15.6 ± 3.0	28.3 ± 4.8	33.5 ± 4.2	743.1 ± 83.3
p-value	0.86	0.89	0.56	0.15	0.80	0.14

	Mindfulness					
	Total	Observe	Labeling	Non-judgmental	Non-react	Awareness
Advanced	121.1 ± 11.8	30.4 ± 5.8	26.5 ± 3.8	21.9 ± 9.0	23.6 ± 5.8	18.7 ± 4.9
Novice	121.3 ± 11.4	29.9 ± 4.5	27.7 ± 4.6	19.7 ± 6.6	23.4 ± 5.3	20.5 ± 4.1
p-value	0.96	0.79	0.43	0.44	0.92	0.27

Notes. Significance level $p < 0.05$
There were no differences between advanced and novice climbers for any of the psychological surveys.

DISCUSSION

One of the main goals of this study was to investigate novice and advanced climbers matched in experience, in order to determine what characteristics differentiate these individuals other than experience. There was no difference in years of climbing nor were there differences in time spent climbing each week, suggesting that there are other, potentially physiological, differences that advanced climbers have in comparison to novice climbers. Identifying the greatest differences between groups, will allow novice climbers to target their greatest weaknesses in order to improve their climbing ability. From the results of this study, some of the tests performed produced distinct differences between climbers.

There were no differences in any of the anatomical anthropometric variables, such as forearm length, hand size, arm span, or ape index, meaning that most of the differences between novice and advanced climbers exist in trainable, rather than inherent anatomical factors (Mermier et al., 2000). Nor were there any difference in height or weight between novice and advanced climbers, similar to previous studies (Grant et al., 2001). However, advanced climbers tended to be significantly leaner than novice climbers (Grant et al., 2001, 1996; G. Laffaye et al., 2016). Climbers must fight against the force of gravity to move their body weight up the wall using muscle. Extra body fat increases the resistance due to gravity, meaning the body has to exert greater forces to move vertically. Therefore, a lean body composition may be advantageous for climbing, though it could also be a result of non-rock climbing exercise (Grant et al., 2001).

There were no differences in the psychological make-up of the novice and advanced climbers. This is in contrast to previous research who found experience correlates with climbing self-efficacy (Llewellyn et al., 2008). In this study, we found that advanced climbers correlated towards having a greater climbing self-efficacy, though we did not find a difference due to the low sample size of this study. The slightly increased self-efficacy of the advanced climbers may be in part due to the increased number and variety of routes they have been exposed to with their increased ability. They may also have been exposed to more risk taking, further increasing their self-efficacy (Llewellyn et al., 2008) Resilience also trended towards significance (p = 0.15), with advanced climbers having greater resilience than novice climbers. One characteristic of bouldering is frequent failure due to falling off a boulder problem. The ability to bounce back and try the same boulder problem numerous times may be a characteristic that advanced climbers have, or have developed with training, more than novice climbers (Galli & Gonzalez, 2015).

Flexibility as a characteristic did not differ between novice and advanced climbers. Similar to some previous studies, flexibility is not a characteristic that determines climbing performance (Mermier et al., 2000), though other studies stated that flexibility does differ between elite and recreational climbers (Grant et al., 2001). However, when each hip flexibility component was examined individually, advanced climbers were able to achieve a greater degree of active hip flexion, but there was no difference in the climbing specific Grant Foot Raise test. This suggests that, hip flexibility is not a distinguishing characteristic of novice or advanced climbing ability.

There were no differences in absolute grip or pincher strength between advanced and novice climbers, but when body mass was taken into account, there were large differences between groups. Because climbers resist gravity while climbing, absolute grip measurements may not be the best variable for characterizing climbers, rather, using measures relative to body weight may be better able to characterize climbers (P. Watts, Newbury, & Sulentic, 1996). It is possible that, by having a higher relative grip and/or pinch strength, advanced climbers are able to climb at a lower percentage of their maximum relative strength, reducing the rate of accumulation of metabolites and staving off the sensation of fatigue (Allen, Lamb, & Westerblad, 2008).

By using a force transducer, we were able to differentiate between pull-up strength, or peak force, and pull-up power, or maximal rate of force development. There were no differences in peak strength, or force, as measured by a force transducer during a pull-up maneuver, suggesting that there may be a minimum amount of strength required for climbing. However, there was a large difference in the rate of force development between groups. This suggests that bouldering, by nature of the explosive types of movement, requires a high amount of power to be successful (Fanchini, Violette, Impellizzeri, & Maffiuletti, 2013; Guillaume Laffaye et al., 2014).

CONCLUSION

In conclusion, we find that advanced climbers have greater relative grip and pinch strength, lower body fat percentage, and greater power than novice climbers. In order for experienced novice climbers to continue to improve, we suggest that they focus on training power, as that was the largest differentiator between groups. Because upper body power proved to be a significant factor in climbing ability, future studies could incorporate lower limb power to determine if it also plays a role in climbing ability.

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