Sport-specific performances in elite youth sport climbers; gender, age, and maturity specifics

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Abstract

Study aim: The increase in the number of professional climbers led to the development of climbers since early age. Therefore, the average age of elite climbers has decreased over the last decade. Consequently, age and maturity specifics should be investigated with the influential factors in climbing. This research aimed to investigate the forearm muscle strength in youth sport climbers and determine the gender, age, and maturity status as factors of influence on forearm muscle performance in elite youth climbers.

Materials and methods: This research included 18 elite sport climbers (Croatian National team members), divided into two age groups: younger (aged 13–15 years) and older (aged 16–18 years). Variables included anthropometric indices (body mass, body height, body fat percentage, ape index), handgrip strength, and climbing-specific forearm strength.

Results: Climbers did not differ between age groups in the studied variables. Also, no significant correlations were found among anthropometric/body-built indices and forearm muscle performances, with age and maturity offset. However, when gender stratified, there were associations between forearm capacity in sitting position and maturity offset in girls (r = 0.73; p < 0.05) but not in boys.

Conclusion: Results could be explained by the assumption that each subsequent generation is better than the previous one. Also, the associations between performance variables and biological age in girls are probably related to girls’ earlier maturity and specificity of sports selection. Forearm muscle capacities are a crucial determinant of success in sports climbing, and a good assessment of these muscle groups could serve as a tool for sport-specific selection.

Keywords: Athlete – Fitness profile – Muscle capacity – Forearm

Introduction

Sport climbing demands a combination of physiological, psychological, technical, and tactical components for success [29]. Numerous previous studies showed the most influential factors for optimal performance [1, 5, 19]. Previously, studies showed that some highly trainable variables are related to climbing success (i.e., relative handgrip strength, upper limb power and endurance, finger strength) [1, 13]. Also, other variables like muscular strength, power, and endurance of the upper body influence performance [29]. Furthermore, according to Guillaume Laffaye, Collin, Levernier, and Padulo [12], some morphological characteristics are essential to climbing success: body mass, height, arm span, forearm diameter, and body fat percent.

Despite the variables mentioned above, researchers have recognized that finger strength has one of the biggest influence on climbing performance [9, 27]. Precisely, finger strength explained 53% of climbing success [7]. In climbing, the fingers produce tension on hold to support the body weight. Therefore, gripping and digit flexion muscles are vital [36]. According to Saul et al. [29], elite climbers, compared to recreational climbers, had significantly higher forearm strength-to-weight ratio, aerobic and vasodilatory capacity, reoxygenation, conductance, and endurance of forearm flexor muscles. Also, previous studies showed that elite climbers perceived significantly higher time to exhaustion than a novice in intermittent finger strength tests [4, 35]. Except for the sustained test, the maximal volunteer contraction test (MVC) showed good relation with climbing performance. According to [15], climbers expelled higher MVC scores than non-climbers. Therefore, maximal finger flexor strength is an important success factor for sports climbing. Following that, assessment of those muscle groups is essential for climbing performance [34].
Since sport climbing was recently included in the official program of the Olympic games, it has developed into a mainstream competitive sport [22], which has influenced an increased number of professional climbers and the development of climbers since youth age. Therefore, the average age of elite climbers participating in international competition is decreasing over the last decade [14]. Consequently, age and maturity specifics should be investigated with the aforementioned influential factors in climbing. However, there is a lack of studies where youth climbers and their performance were evaluated [21]. As in any other competitive sport, of particular importance is the evaluation of factors that could influence competitive achievement [16]. We hypothesized that older climbers would have better results in terms of forearm muscle performance. Also, maturity and age will influence climbers’ performance at the elite level. Following that, the aim of this study was to investigate the forearm muscle strength in youth sport climbers and evaluate age and maturity as factors of influence on forearm muscle performance in elite youth climbers.

**Material and methods**

**Participants**

The sample of participants included 18 youth sport climbers aged 13-18 years, all Croatian national climbing team members (8 females, 10 males). The climbing level based on the International Rock Climbing Research Association (IRCRA) reporting scale was 20 on average, representing an advanced climbing level. The highest redpoint result was recorded as the hardest route that was ever climbed. However, we must emphasize that included climbers do not regularly climb the outdoor rock, and this scale could not be observed as a value of the true performance level of climbers included in this study. They were divided into two age groups: younger (N= 9, aged 13-15 years; 3 females, 6 males) and older (N=9, aged 16-18 years; 5 females, 4 males). During the investigation, the climbers did not have any illnesses or injuries. Athletes were informed about the research procedures, risks, and aims and signed informed consent before initiating the study. Parents or legal guardians signed informed consent for participants under 18. The study followed the declaration of Helsinki, and the Ethical Board of the University of Split, Faculty of Kinesiology, approved the study (no. 2181-205-02-05-22-001; approval date: 05/01/2022).

**Variables and procedures**

This research included anthropometric variables, general fitness, and climbing-specific forearm strength tests.

Anthropometric variables included body mass (BM), body height (BH), body mass index (BMI), arm span (AS), ape index (AS to BH ratio), body fat percentage (BF%), calculated by the Durnin and Womersley formula measuring four skinfolds with using Harpenden skinfold caliper (British Indicators, Burgess Hill, England). BM was measured using the digital scale (Taylor, USA); BH and AS were assessed with the measuring tape. All anthropometric variables were measured in the morning, on an empty stomach.

Maturity offset (MO), as a measure of biological age, was calculated according to the following formula: MO = −7.999 + (0.003 × (age (yrs.) × height (cm))) proposed by [20]. MO predicts years from achieving peak height velocity (PHV).

Generic-fitness tests included a handgrip strength test.

Handgrip strength (HGS) was measured by the electronic hand dynamometer Camry (Model EH101, Zhongshan Camry Electronic Co. Ltd. China). Climbers were doing a test while sitting on the chair with arm fully adducted and 90° flexed elbow. The grip was adjusted for each climber so that distal phalanges of fingers are reaching the dynamometer grip (spherical grip). Each athlete performed three trials of maximal handgrip pressure with each hand, separated by one minute of rest. The highest produced force from three trials was recorded. Maximal results from both hands were averaged as one score and used for further analysis [17].

Climbing-specific forearm strength test included: standing and sitting finger flexor maximal voluntary contraction (STANDMVC and SITMVC, respectively) test. STANDMVC and SITMVC were used to assess the climbing-specific strength of finger flexor muscles. The tests were performed on smart hangboard with integrated force sensors (Climbro, Innovative Hangboards, Bulgaria) on a 23mm deep wooden rung. For STANDMVC climbers were standing in frontal position loading the hangboard rung using their body mass with arm fully extended and using a half-crimp finger position. If the climber managed to lift themselves of the ground, they were given the harness with 10kg weight plates to enlarge their body mass. After preparation, the maximal volunteer contraction (MVC) was done three times, separated by 1-min rest intervals, using the Climbro app protocol [18]. After performing STANDMVC, SITMVC was measured while leaning over a table with the elbow fixed at a 90° angle and the arm fully adducted. The same MVC protocol was used in STANDMVC [31]. Forearm performance variables were reported as absolute values and were relativized according to climbers’ body mass.

**Testing protocol**

Sport climbers were tested during two testing sessions. The first testing session consisted of anthropometric measurements and handgrip dynamometry. The second testing session consisted of climbing-specific
forearm strength tests. Climbers performed universal warm-up before climbing-specific tests, which consisted of 5 minutes of running, 5 minutes of mobility drills, 5 minutes climbing easy boulders (i.e., short climbing routes). Prior to the actual testing procedure, climbers underwent familiarization trials. STANDMVC test was first explained and demonstrated, and then climbers had two submaximal trials on the left and right hand to get the proper form of the test execution. Similarly, SITMVC was explained, demonstrated and climbers tried it before true testing trial.

Statistical analyses

Descriptive statistics (means and standard deviations) were calculated for all variables. Kolmogorov-Smirnov test was used to determine the normality of the variables. Mann-Whitney U test was used to determine the differences between two age groups (younger and older) in all variables for the total sample and gender stratified. Additionally, the receiver operating characteristic (ROC) curve analysis was calculated to confirm the differences between the age groups, with an area under the curve (AUC) of >0.70 indicating the existence of differences in the specific variables.

The Spearman’s correlation coefficients were used to identify the associations between anthropometric and performance variables and age and maturity offset for the total sample and gender stratified.

Table 1. Descriptive statistics between younger and older age groups in all variables

<table>
<thead>
<tr>
<th></th>
<th>Older (N = 9)</th>
<th>Younger (N = 9)</th>
<th>Mann-Whitney U test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age [years]</td>
<td>16.56 ± 0.73</td>
<td>14.22 ± 0.83</td>
<td>0.00</td>
</tr>
<tr>
<td>Climbing experience [years]</td>
<td>8.67 ± 2.22</td>
<td>8.33 ± 1.66</td>
<td>35.00</td>
</tr>
<tr>
<td>Maturity offset [years]</td>
<td>3.61 ± 0.65</td>
<td>1.36 ± 1.20</td>
<td>3.00</td>
</tr>
<tr>
<td>Body weight [kg]</td>
<td>60.14 ± 10.65</td>
<td>54.58 ± 7.16</td>
<td>27.00</td>
</tr>
<tr>
<td>Body height [cm]</td>
<td>170.1 ± 10.70</td>
<td>166.1 ± 8.14</td>
<td>29.50</td>
</tr>
<tr>
<td>Ape index</td>
<td>1.02 ± 0.02</td>
<td>1.03 ± 0.03</td>
<td>31.00</td>
</tr>
<tr>
<td>Body fat %</td>
<td>11.68 ± 5.15</td>
<td>13.38 ± 3.81</td>
<td>32.00</td>
</tr>
<tr>
<td>Handgrip left hand [daN/kg]</td>
<td>0.77 ± 0.08</td>
<td>0.73 ± 0.09</td>
<td>31.00</td>
</tr>
<tr>
<td>Handgrip right hand [daN/kg]</td>
<td>0.78 ± 0.04</td>
<td>0.76 ± 0.10</td>
<td>29.00</td>
</tr>
<tr>
<td>STANDMVC left hand [daN/kg]</td>
<td>0.76 ± 0.07</td>
<td>0.75 ± 0.12</td>
<td>40.00</td>
</tr>
<tr>
<td>STANDMVC right hand [daN/kg]</td>
<td>0.80 ± 0.09</td>
<td>0.79 ± 0.13</td>
<td>38.00</td>
</tr>
<tr>
<td>SITMVC left hand [daN/kg]</td>
<td>0.49 ± 0.10</td>
<td>0.50 ± 0.13</td>
<td>35.00</td>
</tr>
<tr>
<td>SITMVC right hand [daN/kg]</td>
<td>0.56 ± 0.13</td>
<td>0.56 ± 0.15</td>
<td>39.00</td>
</tr>
</tbody>
</table>

STANDMVC – maximal voluntary contraction in the standing position; SITMVC – maximal voluntary contraction in the sitting position; AUC – area under the curve.

All statistical analyses were performed using Statistica ver.13 (Tibco, Palo Alto, California), and a p-level of 0.05 was applied.

Results

Descriptive statistics and differences between age groups in all variables are presented in Table 1. There are no differences between older and younger climbers in the anthropometric and performance variables. Figure 1 represents ROC analysis for differences between age groups. ROC confirmed that the differences do not exist in specific variables.

Spearman’s correlation coefficients between anthropometric and performance variables and age and maturity offset for the total sample and gender stratified are presented in Table 2. Only body weight and body height are correlated with age and maturity offset in males, while forearm muscle performance in the sitting position is correlated with maturity offset in females.

Discussion

This study aimed to investigate the forearm muscle strength in youth sport climbers. Precisely, to determine the gender, age, and maturity status as factors of influence.
Figure 1. Receiver operating characteristics (ROC) curves for forearm performance variables on the dominant hand: A) handgrip; B) maximal voluntary contraction in the standing position (STANDMVC); C) maximal voluntary contraction in the sitting position (SITMVC)
on forearm muscle performance in elite youth climbers. Results did not reveal differences in studied variables between age groups. Also, in total sample, no significant correlations were found among anthropometric/body-built indices and forearm muscle performances, with age and maturity offset. However, when gender stratified, there were associations between forearm capacity in sitting position and maturity offset in girls, but not in boys.

The lack of associations between forearm muscle capacity and age in the total sample could be explained by sports climbers entering the competitive world at very early age. Indeed, with constant growth in popularity, incoming generations are getting into sports climbing younger than ever [11]. Moreover, organized training nowadays starts as early as the age of 5, which was not present 10 years ago (as authors are experienced climbers, they can relate). This leads to each subsequent generation being better than the previous one as sports climbing expands and provides an additional possibility for development.

The first reason for increased and faster development is improved infrastructure. For example, a growing number of climbing gyms can be seen in the U.S. where 25% more gyms opened in 2020 than in 2015 [32]. This trend provides better infrastructure for training and competing and diversity for climbers and trainers. Except for the growing number of climbing gyms worldwide, the development lies in emerging scientific methods to evaluate and enhance performance [15, 28]. Precisely, scientific evidence leads to a better understanding of climbers’ physiological and psychological response and performance development.

The indication that young climbers achieve high-performance levels and competitive achievements could be the fact that current Olympic champions in sports climbing are 20 (male) and 22 (female) years old [10]. Also, 23.52% of female climbers who qualified for the semi-finals or finals of World Cup were very young, entering the highest stages of competition from the age of 16 [33]. According to the aforementioned, it can be noted that climbers are reaching high performance at a young age. Similar trend was previously shown in other sports. Precisely, sport gymnasts are entering sport at the age of 7, and specializing at the age of 9 [25]. According to [37], most talented climbers are relatively young. They noted that high-level young competitive climbers present general anthropometric characteristics similar to elite adult climbers (i.e., small stature, low body mass, low sum of skinfolds, and high handgrip/mass ratio). Similarly, a previous study by [3] has shown that young (boys with age 15.2 ± 1.9 years, girls 14.2 ± 1.8 years) and adult elite climbers (males 27.5 ± 8.1 years, females 25.5 ± 5.5 years) have similar anthropometric and strength characteristics (i.e., low body fat, high performances in bent-arm hang, grip strength related to body mass and meters climbed per week). The studies above support our theory that youth climbers are similar to adults regarding the anthropometric and performance variables and reach high performance at early ages [26, 30].

Table 2. Spearman’s correlation coefficients between anthropometric and performance variables, and age and maturity offset

<table>
<thead>
<tr>
<th>Total sample</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>MO</td>
<td>Age</td>
</tr>
<tr>
<td>Body weight</td>
<td>0.391</td>
<td>0.300</td>
</tr>
<tr>
<td>Body height</td>
<td>0.259</td>
<td>0.197</td>
</tr>
<tr>
<td>Ape index</td>
<td>-0.182</td>
<td>-0.018</td>
</tr>
<tr>
<td>Body fat %</td>
<td>-0.052</td>
<td>0.245</td>
</tr>
<tr>
<td>Handgrip left hand</td>
<td>0.107</td>
<td>-0.005</td>
</tr>
<tr>
<td>Handgrip right hand</td>
<td>0.252</td>
<td>0.224</td>
</tr>
<tr>
<td>STANDMVC left hand</td>
<td>0.240</td>
<td>0.102</td>
</tr>
<tr>
<td>STANDMVC right hand</td>
<td>0.272</td>
<td>0.061</td>
</tr>
<tr>
<td>SITMVC left hand</td>
<td>0.111</td>
<td>-0.020</td>
</tr>
<tr>
<td>SITMVC right hand</td>
<td>0.064</td>
<td>-0.018</td>
</tr>
</tbody>
</table>

STANDMVC – maximal voluntary contraction in the standing position; SITMVC – maximal voluntary contraction in the sitting position; MO – maturity offset; * denotes p < 0.05, ** denotes p < 0.01; *** denotes p < 0.001.
Our results also showed associations between forearm capacity in sitting position and maturity offset in girls but not boys. The main reason for recorded associations among girls could be their earlier maturation and development. Supportively, previous studies have shown that the development for girls starts at 10–11 years, whereas for boys it is at 14–15 years old [16]. Indeed, the influence of earlier maturation among girls in sports climbing was previously shown in a study that examined physiological responses to rock climbing in young climbers [21]. In their research, different influential characteristics (i.e. skeletal development, body mass, body fat, strength) were observed in accordance with maturation among young climbers. Also, according to Pichardo et al. [24] maturity offset influences motor skill performance in adolescent boys. In their study, maturity offset had significant correlation with some motor skills (i.e., jumping, sprinting), and is influential for performance.

Another reason for recording associations between forearm capacity in sitting position and biological age among girls could be related to the selection of sport climbers in Croatia. Precisely, there are more females than males among competitive climbers in all age categories (63.63% females) [8]. Thus, there is a broader selection of girls and a better possibility for selecting high-performing girls.

Sports performance depends on an athlete’s technique, motor performance and physical fitness (body dimensions, sport-specific and general fitness capacities) [23]. Therefore, advancements in the technique can influence the full exploitation of sports potential. Furthermore, in sports climbing, girls got a tendency to rely more on technique and use energy more efficiently than males [2]. A previous study showed that relative handgrip strength could be used for investigating fatigue levels and, thus, the effectiveness of a climber’s performance. Precisely, climbers get a 22% decrease in handgrip strength after lead climbing, indicating fatigue [36]. Supportively, Gajewski and Jarosiewicz [6] showed a decrease in handgrip strength in adult (male 27.4 ± 7.6 years, females 25.4 ± 7.2 years) climbers. In their research, female and male groups did not differ in climbing ability, while relative handgrip of females was significantly lower than male climbers. In spite of that, females showed slighter decrease in handgrip strength post-climbing, which positively affects their climbing ability. At the same time, males use more strength while climbing and therefore show a more significant decrease in handgrip strength post climbing. Therefore, this resistance to fatigue in handgrip performance among females may indicate more effective climbing and increased use of climbing technique over strength.

**Limitations and strengths**

The main limitation of this study comes from the small sample of included climbers. Thus, the results should be observed and interpreted with caution. However, the reason for such a small sample size lies in the quality of the participants. To be more specific, we included only national team members from a small European country, which is probably one of the most important strengths of this research. Indeed, evaluating the best competitive athletes is always a challenge, as they represent a very specific and narrow sample. Also, as the majority of the National climbing team members are youth who participate at the highest levels of competition (i.e., European and World championships), evaluating them could make a significant contribution for both scientists and coaches.

**Conclusion**

Young elite climbers did not differ between age groups in the studied variables. Also, in the total sample, no significant correlations were found among anthropometric/body-built indices and forearm muscle performances, with age and maturity offset. However, there were associations between forearm capacity in sitting position and maturity offset in girls, but not in boys. The associations between performance variables and biological age in girls are probably related to girls’ earlier maturation and specificity of sports selection in sports climbing. Thus, future studies should investigate this issue among older climbers who finished their growth and maturation processes.

As forearm muscle capacities are a crucial determinant of success in sports climbing, a proper assessment of these muscle groups could serve as a tool for good sport-specific selection. Therefore, future studies should more detailly investigate top-level youth climbers’ forearm muscle capacities (e.g., forearm muscle oxygenation).

**Conflict of interest:** Authors state no conflict of interest.

**References**


