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Fitness Profiling in Top-Level Youth Sport Climbing; Gender Differences

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Abstract

Sport climbers should possess specific anthropometric characteristics and conditioning capacities to reach a top level in this sport. PURPOSE: The purpose of this study was to determine gender differences in the fitness status of the top-level youth sport climbers. METHODS: The study was conducted on 20 elite Croatian youth sport climbers (all members of the national team, ten females; 13-18 years of age). The variables included anthropometric status (mass, height, arm span, and body fat percentage), generic- (countermovement- and squat-jump, grip strength), and specific-fitness tests (power slap test and Draga foot lift). RESULTS: Boys were taller than girls (t-test=2.51, p=0.02, moderate effect size (ES)), and had lower body fat percentage (t=-5.66, p=0.001, very large ES). Boys achieved better results in countermovement- (t=5.39, p=0.001, very large ES) and squat-jump (t=2.19, p=0.04, moderate ES), while there were no gender differences in the specific fitness tests. CONCLUSION: Gender differences were observed in generic but not in specific fitness, which may indicate that climbing is a specific sport that requires and develops specific abilities in a similar way in boys and girls.

Keywords: *climbers, generic tests, sport-specific tests, conditioning capacities, youth athletes*

Introduction

Sport climbing is a new Olympic sport that involves climbing variable rocks using only the athlete's body (Sanchez et al., 2019). According to international standards, professional sport climbers compete exclusively on artificial walls. The popularity of sport climbing is growing rapidly; according to the International Federation of Sport Climbing (IFSC), 35 million people worldwide participate in sport climbing (International Federation of Sport Climbing, 2015). Sport climbing is a polystructural acyclic activity that requires specific psycho-tactical, physiologic-anthropometrical, and coordination-technical aspects for successful performance (Magiera et al., 2013).

Previous studies point to multiple characteristics that define performance in elite sports climbers (Fuss & Niegl, 2010; Michailov et al., 2015; Assmann et al., 2020). Anthropometric parameters like body mass, height, arm span, forearm diameter, and body fat percent are essential determinants of climbing success (Laffaye, Collin, et al., 2014). Specifically, according to MacKenzie et al. (2020), low body fat percentage is the anthropometric parameter that correlates with success the most. In a study by Laffaye et al. (2016), better climbers had higher ape index (arm span to height ratio). However, general fitness tests (Countermovement jump, isometric Sorensen test, Bench press test) showed no connection to climbing performance, associated with success or gender (Laffaye, Collin, et al., 2014). Nevertheless, handgrip strength to body mass ratio is the only general fitness predictor of sport climbing success (Laffaye et al., 2016; Assmann et al., 2020).

It is generally accepted that climbing-specific tests are good predictors of climbers' performance and can differen-

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tiate them based on their success (Saul et al., 2019; Draper et al., 2021). One parameter that differentiates elite climbers from the general population and novice climbers is finger strength and forearm flexor endurance (MacLeod et al., 2007). Namely, sport climbing requires constant and long-term loading of the finger and forearm flexors. Therefore, the endurance of the se muscle groups is one of the most important factors for climbing performance (Valenzuela et al., 2015). The endurance of shoulder girdle muscles is also connected with climbing success (MacKenzie et al., 2020). Modern competitive climbing requires various dynamic-acrobatic movements and exceptionally difficult motions. For this reasons, climbers must have explosive power and highly developed movement coordination (Fuss & Niegl, 2010). In addition, better climbers have better hip flexibility and mobility for more efficient movements (Draper et al., 2017). The above parameters are equally important in both genders (Philippe et al., 2012).

In order to objectively define the state of important climbing skills, it is necessary to determine a gender-specific model that athletes strive for in the training process. However, the studies that investigate the gender differences are scarce, and the studies that have been conducted show contradictory results. According to the study of Philippe et al. (2012), there are no differences between male and female elite and high-level performance climbers (21-32 years old) in terms of forearm and finger flexor muscle fatigue. Furthermore, differences among male and female elite climbers (24-37 years old) were not found in general fitness tests (sit & reach relative handgrip strength) (Espana-Romero et al., 2009). However, Wu et al. (2011) show the results from Chinese elite climbers (23-38 years old), where gender differences in handgrip strength are found (males have better results). Regarding anthropometric characteristics, male climbers had lower body fat percentage, longer arm length, and higher BMI compared to females (Espana-Romero et al., 2009).

From the overview of previous research, it can be seen that most of the studies on anthropometric and fitness determinants were conducted on older climbers (>20 years old) (MacKenzie et al., 2020; Saul et al., 2019). Considering that competitions in sport climbing are held from <10 years old, it is clear that there is a need to determine fitness profiles for younger age categories. Finally, there are few studies that examine gender differences, with contradictory findings (Philippe et al., 2012; Schoffl et al., 2011). This purpose of this study was to determine the gender-specific fitness profile of elite youth sport climbers (13-18 years old). More specifically, it aimed to determine the gender differences in anthropometric, general, and specific measurements of conditioning capacities among top-level youth sport climbers in Croatia (members of the national team). By determining the fitness profile of youth sport climbers, it could be possible to develop better training programs and optimally develop their performance.

Methods

Participants

This study included 20 youth sport climbers aged 13-18 years, all Croatian members of the national climbing team. All climbers were neither ill nor injured during the study. Athletes were informed about the procedures, risks, and aims of the research and signed the informed consent before initiating the study. Parents or legal guardians signed the informed consent for participants under the age of 18. The Ethical Board of the University of Split, Faculty of Kinesiology, Split, Croatia, approved the study (Ref. no:2181-205-02-05-22-001, Date of approval: 05/01/2022).

Variables and procedures

This research included anthropometric variables, as well as generic and specific fitness tests.

Anthropometric variables included body mass (BM), body height (BH), body mass index (BMI) calculated as BMI=BM(kg)/BH(m)2, arm span (AS), ape-index (AS to BH ratio), body fat percentage (BF%) calculated by Durnin and Womersley formula measuring four skinfolds with using Harpenden skinfold calliper (British Indicators, Burgess Hill, England).

Generic-fitness tests included countermovement jump (CMJ) test, squat jump (SJ) test, and handgrip strength (HGS).

CMJ and SJ tests were used for measuring the explosive strength of lower limbs and were assessed by the Optogate System (Microgate, Bolzano, Italy). CMJ was performed by climbers standing upright between two photoelectric beams with hands placed on their hips. They moved downwards with knees bending to approximately 90° and performed maximal upward movement-jump. SJ was conducted in the same setting, but athletes started the jump from a position with approximately 90° bent knees and without any downward movement. Athletes performed three trials for CMJ and SJ, with one-minute rest between the trials and 5 minutes rest between the tests. The best score (cm) from CMJ and SJ was taken for analysis.

HGS was measured by the electronic hand dynamometer Camry (Model EH101, Zhongshan Camry Electronic, China). Athletes were sitting on the chair with arm fully adducted and 90° flexed elbow. The use of the thumb and other hand was not allowed while applying the maximal pressure. 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 (Medernach et al., 2015).

Specific fitness tests included: (i) Power slap test (SLAP) and Draga foot lift (DRAGA).

SLAP was used to assess the climbing-specific power of shoulder girdle muscles (Figure 1). The test was performed on the 20° overhang board 150 cm high and on the positive 35 mm deep wooden rung. Before the test initiation, the maximal arm reach was recorded for each hand. The test started with the participants hanging on the rung with straight arms and legs off the ground. The climber had to perform an explosive pull-up and slap with one arm as high as possible (Draper et al., 2021). The test result was calculated by subtracting the supported arm reach from maximal jump height. Participants performed three jumps on each hand, separated by 1.5 minutes of rest between the trials. The highest jump height on each hand was taken in further analysis.

DRAGA was used to evaluate climbing-specific hip joint mobility (Figure 2). Participants stood upright with their back

FIGURE 1. Power slap jump test: starting (A) and ending (B) position.

supported on the gymnastic wall bar and pelvis stabilized with a belt attached to the bar. Participants held their hands on the bar to stabilize their trunks. They performed outside rotation with the foot and maximally raised leg with a bent knee. The result of the test was the distance in centimetres from the ground to the heel of the lifted leg (Draga et al., 2020).

FIGURE 2. Draga foot lift test: starting (A) and ending (B) position.

Testing protocol

Sport climbers were tested during two testing sessions. The first testing session consisted of anthropometric measurements, HGS, CMJ and SJ tests. The second testing session consisted of climbing-specific tests: SLAP and DRAGA. Climbers performed universal warm-up before the climbing-specific tests, which consisted of 5 minutes running, 5 minutes of mobility drills, 5 minutes climbing easy boulders. Prior to the actual testing procedure, climbers underwent familiarization trials. SLAP was first explained, demonstrated and then climbers had two submaximal trials on the left and right hand to get the proper form of the test execution. Similarly, DRAGA was explained, demonstrated and climbers tried twice on each leg to feel the test procedure.

Statistical analyses

The non-uniformity of error was reduced by log-transforming the data. Statistical analyses were conducted on log-transformed data, but the results in the tables are presented as actual values (non-log-transformed). The Kolmogorov Smirnov test tested the normality of the variables. Descriptive statistics (means and standard deviations) were calculated for all variables. T-test for independent samples was calculated to determine gender differences in the studied variables. Additionally, Cohen's d effect sizes (ES) were calculated for gender differences in the studied variables, and they were interpreted as: <0.2 = very small; 0.21–0.49 = small; 0.50–0.79 = moderate; ≥0.8 = large; ≥1.2 = very large ES (Cohen, 2013).

The inter-item reliability was checked for fitness tests by calculating Inter-Item Correlation (IIC) and Cronbach's Alpha (CA) from three testing trials. Additionally, repeated-measures ANOVA was analysed for checking the differences among three trials.

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

Results

The reliability of the generic and specific fitness variables is shown in Table 1. All fitness variables had very high reliability, with Cronbach's alpha coefficients ranging from 0.95 to 0.99. in addition, repeated-measures ANOVA showed no differences between the testing trials in all tests, except for the CMJ test.

Table 1. Reliability of the fitness variables for the total sample

	Inter-Item correlation	Cronbach's Alpha	ANOVA F-test (p)
Countermovement jump	0.99	0.99	3.84 (0.03)
Squat jump	0.95	0.95	0.21 (0.81)
Handgrip left hand	0.99	0.99	1.58 (0.22)
Handgrip right hand	0.97	0.97	3.12 (0.06)
Power slap left hand	0.99	0.99	3.24 (0.05)
Power slap right hand	0.99	0.99	1.95 (0.16)

Descriptive statistics and differences between male and female climbers are shown in Table 2. Boys are taller than girls (t-test=2.51, p=0.02, ES=1.12), and have lower body fat percentage (t=-5.66, p=0.001, ES=2.53). Boys performed better in the countermovement (t=5.39, p=0.001, ES=2.41) and squat jump (t=2.19, p=0.04, ES=0.98). There were no differences between male and female climbers in specific motoric tests.

Table 2. Descriptive statistics (means and standard deviations) and gender differences in anthropometric characteristics and fitness indices.

	Boys		Girls		t-test	
	Mean	SD	Mean	SD	t-value	p
Body mass (kg)	59.99	10.68	53.03	5.98	1.79	0.09
Body height (cm)	171.76	9.06	162.72	6.93	2.51	0.02
Body mass index	20.16	1.78	19.99	1.41	0.23	0.82
Ape index	1.02	0.02	1.03	0.02	-0.84	0.41
Body fat (%)	9.48	2.64	16.99	3.27	-5.66	0.001
Countermovement jump (cm)	33.88	5.88	22.75	2.82	5.39	0.001
Squat Jump (cm)	25.93	4.30	22.51	2.44	2.19	0.001
Handgrip strength (kg/kg)	0.77	0.09	0.74	0.07	0.85	0.40
Power slap (cm)	27.30	12.73	19.50	8.60	1.55	0.14
Foot lift (cm)	74.20	4.80	76.53	8.31	-0.77	0.45

Discussion

There are several important findings in this study. First, males are taller and have lower body fat than females. Regarding the generic tests, males performed better in CMJ and SJ tests than females. However, we found no gender difference in the applied sport-specific tests of conditioning capacities.

Anthropometric characteristics

Males are taller and have lower body fat compared to females. These results are logical and have been confirmed in numerous previous studies on the non-trained population and athletes (Watts & Jensen, 2003; Schoffl et al., 2011). This is primarily due to the secretion of sex hormones and genetic imprint (puberty is manifested by an increased secretion of testosterone in boys, followed by the development of muscle mass and the lower accumulation of fat tissue) (Karastergiou et al., 2012). For the purpose of our study, it is important to note that previous studies from the USA show a significantly lower body fat percentage in competitive climbers (13.0%) than in their 10-15 year old non-climber peers (18.7%) (Watts & Jensen, 2003). The same study showed that climbers are slightly shorter than non-climbers (158.5 cm and 167.1 cm, respectively). Supporting this, our study showed that the height of Croatian climbers is in the 50th percentile for females and males of the same age in Croatia (Juresa et al., 2012), while Croatian male climbers are in the 15th, and female climbers in the 25th percentile. This suggest that the anthropometric fitness profile of climbers is characterized by a slightly lower body height.

The results of the Croatian climbers show no differences between genders in body mass, ape-index, and arm span. A possible explanation is that the studied climbers are still in the growth and development period and have not yet reached their final body dimensions (Malina, 1994). However, regardless of the non-significant differences between genders, the reported anthropometric parameters of young climbers are important determinants of climbing performance.

Generic conditioning capacities

Although the importance of the vertical jump for climbers is not often emphasized, the specificity of modern sport climbing requires lower body power (i.e., powerful movements and jumps on large surfaces on the climbing wall). Thus, the importance of developing and testing generic jumping performance should be addressed. In our study, male climbers achieved better results than females in vertical jumps. It is regularly confirmed that males achieve better results in the vertical jump test because they have higher muscle mass, followed by hormonal functions (Laffaye, Wagner, et al., 2014). The better vertical jump performance in males is confirmed by previous studies comparing athletes in various sports (Laffaye, Wagner, et al., 2014). Our results are generally consistent with previous reports where adult climbers were examined. In particular, the study by Espana-Romero et al. (2009) found differences between male and female climbers aged 25-30 years in the CMJ test (34.1±4.43 cm for males, 28.6±3.08 cm for females). Similar results were also found in our study in the CMJ test (33.88±5.88 cm for males and 22.75±2.82 cm for females).

We found no gender differences in HGS measured by a dynamometer. This finding is not consistent with common data, which shows that males generally perform better than females in HGS (Ahrenfeldt et al., 2018). Therefore, it could be assumed that male and female climbers are equally developing HGS, unlike the general population. Irrespective of the lack of gender-differences, the results of Croatian climbers (42.7 kg) are similar to those of French novice climbers (45.8 kg) (Laffaye et al., 2016). The previously cited French study showed that HGS in the dynamometer test does not correlate with performance in sport climbing as it is not a specificity of the sport (i.e. climbing grips involve more strength of the finger flexor muscles than forearm strength). However, climbers have a much higher HGS than the general population (34,6 kg) (Ahrenfeldt et al., 2018). Therefore, it could be assumed that the assessment of HGS contributes to the modeling of the young climbers' fitness profiles.

Sport-specific tests of conditioning capacities

Although numerous studies show that sport-specific tests in climbing are good indicators of climbing performance (Michailov et al., 2015; Laffaye et al., 2016), specific tests applied in our study did not discriminate boys from girls.

First, DRAGA mobility test did not distinguish boys and girls in our research, which is in contrast to a previous Spanish study that showed better flexibility results for female climbers compared to male climbers (Espana-Romero et al., 2009). The better mobility and flexibility of the hips is explained by a wider pelvis and greater hip and pelvic angles in females (Mier & Shapiro, 2013). However, we included youth climbers who are still in the growth and development phase. Thus, the gender differences may not have occurred yet. Therefore, the results of the DRAGA test should be observed only from the perspective of youth climbers and should not be related to older climbers.

In addition, boys would be expected to achieve better results in the SLAP test than females simply because of the differences evidenced in generic jumping capacities, but also due to the greater percentage of lean body mass, body dimensions, and hormonal influence (Draper et al., 2021). Indeed, the SLAP test evaluates the (upper) body power; therefore, the listed characteristics should significantly affect differences between males and females. The reasons for the lack of gender differences in the SLAP test in our study could be explained in several ways. First, according to a database of the Croatian Federation of Sport Climbing, there are more females than males among competitive climbers in all age categories (63.63% females) (Hrvatski Sportsko Penjački Savez, 2021). Therefore, the better sport-selection among females could be the reason why the girls in our study achieved similar results as boys. Second, climbing is not a sport exclusively performed by males. Females achieve similar climbing results. Namely, according to Carroll (2021), three females are among the top 90 climbers of all time. For a simple comparison, in the 100m-dash sprint, the best female result is at 2000th position when males and females are combined. Therefore, it is possible that girls achieve similar results as males in sport-specific tests at top youth level, as the one we studied here.

Regardless of the lack of gender differences, it is also important to note that the Croatian climbers perform worse than other elite climbers in specific tests (SLAP and DRAGA) (Draper et al., 2017; Draper et al., 2021). However, as most previous studies examined older athletes (Espana-Romero et al., 2009; Draper et al., 2021), it could be assumed that our climbers have not yet reached their final stage of development and consequently their maximum performance in specific tests. Therefore, it is possible that with advanced years and with the final morphometric development, gender differences will become more pronounced. Thus, the results of this study should be observed and interpreted with caution, as the climbers have probably not developed their full potential yet.

Conclusion

Young elite climbers differed in body height (boys were taller) and body fat percentage (boys had a lower percentage) but not in body mass and ape index. Differences were recorded in general fitness tests (vertical jump), while boys and girls did not differ in any climbing-specific tests. The results may suggest that climbing is a specific sport that requires and develops specific abilities in a similar way in boys and girls. Since we also included youth climbers, the absence of gender differences could be explained by the fact that climbers have not yet reached their final stage of development and their full capacity to perform sport-specific tests.

Future studies should examine the fitness profile of top-level youth climbers in more detail to determine anthropometric characteristics and conditioning capacities that are crucial for success in this sport.

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Conflict of Interest
The author declares that there is no conflict of interest.

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