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Intersexual Differences and Relationship of Specific and General Muscle Strength of Young Sports Climbers

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Abstract

Climbers benefit from a combination of general and specific strengths, which are tailored to meet the demands of climbing. The aim of the study is to assess the intersexual differences of general and specific muscle strength and the gender-specific relations between specific and general muscle strength of youth boulderers. The research sample consisted of 26 young climbers divided into two groups according to gender. To assess general muscle strength climbers performed hand dynamometry, bent- arm hang and hang on bar. From the viewpoint of assessing specific muscle strength, testing included maximal flexor-finger strength test, bent-arm hang on hangboard, finger hang test. The intersexual differences were evaluated by Mann-Whitney U test, while the relationships between general and specific muscle strength were evaluated by Spearman's rank correlation coefficient. The correlation analysis of boys muscle strength showed statistically significant relationship between the relative strength of the hand grip and maximum finger strength ($p<0.05$; $r=0.58$) and also strength endurance of back and forearm muscles ($p<0.01$; $r=0.73$). Statistically significant relationship between general and specific strength endurance of back and forearm muscles was proven for girls muscle strength ($p<0.01$; $r=0.87$). The findings suggest that appropriate assessment of specific and general muscle strength could serve as a tool for sport-specific selection.

Keywords: *climbing, sport-specific tests, young athletes, strength parameters*

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Introduction

With the growing popularity of sport climbing, more and more young people are taking up this sport at a very young age, while currently organized training starts at the age of around 5 years, which has caused that incoming generations are getting into sports climbing younger than ever (Kozina et al., 2016). In the last few decades the most talented climbers have been relatively young. The 2019 female World senior climbing medalist

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were aged 15 years, an age that can also found among adult World cups competitors. Data of young climbers are rare but currently, there are few researches that deal with fitness profiling (Gilič,Vrdoliak 2023; Vrdoliak, Gilič and Skontic 2022), physiological responses (Morrison and Schöffl 2007) and tactical and psychological training models of young sports climbers (Trifu, Stănescu, and Pelin, 2021).

From the point of view of the structure of sports performance in climbing, strength plays a crucial role in a climber's performance, encompassing both general and specific strength attributes. General muscle strength refers to overall muscular capability, including the strength of large muscle groups used in a variety of movements, not limited to climbing. España-Romero et al. (2010) highlighted the importance of general strength training for climbers, noting that core and upper body strength contribute significantly to overall climbing performance, even if not directly tailored to climbing movements. Watts et al. (2008) identified general fitness parameters, including aerobic capacity and muscle endurance, as foundational to climbing performance, suggesting that while not specific, these aspects are still crucial for overall athletic conditioning.

Specific muscle strength in climbers refers to strength that is directly applicable to the unique demands of climbing. Mermier et al. (2000) demonstrated that while general strength attributes contribute to climbing, specific strength metrics, like grip strength and finger endurance, are more directly correlated with climbing success, particularly in difficult routes and bouldering problems. The maximum strength and muscle endurance of the finger flexors are considered the main determinants (Assmann et al., 2021; Laffaye, Levernier and Collin, 2016). It requires repeated isometric contractions of the finger flexors, the intensity and duration of which vary depending on the size and composition of the "hold" that the climber is grasping and the movements he is performing (Amca et al., 2012).The most frequently used test of maximum isometric strength of the forearm muscles in climbing research is hand dynamometry (Gilič, Vrdoliak 2023; Cheung et al., 2011; Michailov et al., 2015). The reliability of this test has been repeatedly verified in different populations (España-Romero et al., 2010; Schetman, Gestewitz, Kimble, 2005).The finger hang test is also often used, which mainly reflects the strength endurance of the finger flexors (Kodejška and Balaš 2016). It turned out that this test has a very strong relationship with RP performance in both women and men (Balaš et al., 2012).

The endurance of shoulder girdle muscle is also connected with climbing success (MacKenzie et al., 2020). According to several authors (Balaš et al., 2012; Draper et al. 2021; Kalayci and Baskan 2023; Michailov at al. 2018) a higher strength of the shoulder girdle and finger flexors is associated with an increase climbing performance, which caused the creation of a number of climbing tests. Bent-arm hang is one of the general tests and was taken over to climbing. The test focuses on the strength and endurance requirements of the upper limbs and shoulder girdle (Kodejška and Balaš 2016).

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In order to optimize climbing performance, it is also necessary to focus on the sex differences that this sport brings. Gender differences in sports climbing can be observed in various aspects such as physical attributes, performance, participation rates, and competitive dynamics. Generally, male climbers have higher upper body strength and greater muscle mass, which can give them an advantage in routes that require powerful moves or dynamic movements (Mermier et al 2000; Grant et al. 2001). Female climbers often have better flexibility and a lower center of gravity, which can benefit them on routes that require balance, precision, and technical skill. They may excel in technical routes that emphasize technique over raw power (Watts et al. 2003).Bouldering is a discipline which requires short bursts of power and strength. Men typically excel due to their upper body strength, but women often perform well on problems that prioritize technique and flexibility (Draper et al. 2011).The study by Baláš et al. (2012) also indicates that there are differences in the structure of sports performance between genders. However, there is a lack of studies investigating gender differences in young climbers. The study of Vrdoliak, Gilič and Skontic (2022) confirmed that there are differences in body composition between the sexes, however no gender difference in the applied sport-specific tests of conditioning capacities was found. Another study of Gilič and Vrdoliak (2023) demonstrated associations between forearm capacity in sitting position and maturity offset in girls, but not in boys.

The aim of the study is to assess the intersexual differences of general and specific muscle strength of youth boulderers. Additionally, the aim was to investigate the gender-specific relations between specific and general muscle strength.

Methods

Participants

The research sample consisted of 26 young sports climbers divided into two groups according to gender. The climbing level based on the International Rock Climbing Research Association (IRCRA) reporting scale representing an advanced climbing level for girls and intermediate level for boys. The observed climbers performed the training process twice a week for 90 minutes. The research sample was selected according to following criteria: uninterrupted training process of at least 3 months before inclusion in the research, without injuries, recreational competitor, bouldering as sport discipline. The exclusion criteria were: lead or speed as sport discipline, injuries, no competition achievements. Detailed description of research sample is presented in Table 1.

Participants were instructed to avoid engaging in intense physical activity within 24 hours before the testing session, as well as consuming caffeine within 12 hours previous to the testing session, so order to prevent any possible performance-enhancing effects acording Guest et al.(2021).

Table 1: Description of research sample

Gender	n	Decimal age (years)	Sports age (years)	IRCRA scale	Body height (cm)	Body weight (kg)	BMI (kg/m^2)
		Median±quartile deviation					
Boys	16	14.20±0.96	2.75±1.94	17	168.40±4.16	49.25±5.83	17.55±1.25
Girls	10	12.75±0.78	3.75±0.88	18	155.65±3.31	44.90±6.13	18.20±1.48

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Procedures

The participants were tested during two testing sessions with two day rest between them. At the beginning of the first testing session participants were tested on anthropometric indices. Subsequently, the participants performed warm-up with the trainer consist from 5 minutes general warm-up and 15 minutes specific warm up on the wall where performed 5 minutes of an easy climbing traverse followed by 10 min of progressive bouldering (50–80% of their maximum). During the warm-up boulders, the participants had a minimum of 1-min rest between boulders and ~10 min of rest before testing accoriding to Hermans et al. (2022).

After the warm-up the participants performed 3 general muscle strength tests (hand dynamometry for dominant and non-dominant hand, hang on bar, bent-arm hang) and 3 specific muscle strength test (maximal flexor-finger strength test for dominant and non-dominant hand, finger hang test, bent-arm hang on hangboard). The tests were selected based on available scientific articles, according to the testing methodology of several authors (Draper et al. 2021; Kalayci and Baskan 2023; Michailov at al. 2018; Mermier et al. 2000; Winnick and Short 2014). General tests were performed using hand dynamometer Lafayette 78010 (Lafayette Instrument Company, Lafayette, USA) and bar. Specific tests were performed using a Climbro hangboard (Climbro Ltd., Sofia, Bulgaria) mounted on a vertical hanging platform. Climbro has integrated force sensors (sample rate 100 Hz) and phone application Climbro providing instructions and real-time feedback about force and time of muscle contraction.

Hand dynamometry for dominant and non-dominant hand

The tested person, in standing position grasped hand dynamometer by the dominant hand and gradually exerted the maximum pressure. The pressure was graduated for at least two seconds. After recording the result, the non-dominant hand was measured. During the grip, the outstretched hand was not allowed to touch any part of the body. The movable part of the handle was adjusted to reach the first phalanx of the ring finger. Two attempts were made and the best result for both hands was recorded to the integer number. The relative strength of the hand grip and finger flexors was expressed by the ratio of the climber's absolute strength and weight.

Bent-arm hang

The test is aimed at evaluating muscle endurance of shoulder girdle and back muscles. The tested person tried to hold onto the 2.5 diameter metal bar in the pull-up position, for as long as possible. The grip width matched that of the shoulders. The chin was kept above the bar level. The tested person was taken up to the required position and when person was ready to start the time started. The chin was not allowed to touch the bar during the test. The tested person was verbally supported. The test was finished at the moment when the chin sank under the bar level. The result was measured with accuracy of 0.1 s.

Hang on bar

The test is aimed at evaluating endurance of forearm muscles. The tested person stands under the bar and grabs the bar with both hands. The grip width matched that of the shoulders. After the start signal sounds the tested person hangs onto the bar for as long as possible. The test was finished after the tested person was unable to continue hanging. The test result was recorded with an accuracy of 0.1 seconds.

Maximal flexor-finger strength test for dominant and non-dominant hand

The test is aimed at evaluating the maximum finger strength. The test is performed by applying the maximum force that tested person knows generate with one hand on 2.3 centimeters hold with an open grip. The tested person stands under the hold with arms at approximately 180° shoulder flexion with slightly flexed elbow and knees and grabs the hold with the chosen arm and open grip. After the start signal sounds, the tested person gradually loads the hold by bending the knees but feet are still touching the ground so that he weighs the chosen hand the most. The test person must not „pull" by bending the elbow of chosen arm. The tested person has 5 seconds to load the hold as much as possible. The test ends automatically after two repetitions with each arm. If tested person is able to hang on the hold during the test, an additional load is added.

Bent-arm hang on hangboard

The test is aimed at evaluating shoulder girdle and back muscles and forearm muscles muscular endurance. The tested person tried to hold onto the 30 mm hold in the pull-up position, for as long as possible. The grip width matched that of the shoulders. The chin was kept above the hold level. The tested person was taken up to the required position and when person was ready to start the time started. The chin was not allowed to touch the hold during the test. The tested person was verbally supported. The test was finished when the person was unable to hold onto the rung. The result was measured with accuracy of 0.1 s.

Finger hang test

The test is aimed at evaluating strength endurance of forearm muscles. The test is performed on 30 mm deep edge with 12 mm radius wooden hold. The tested person stands under the hold and grabs the hold with both hands. After the stars signal sounds, the tested person hangs onto the hold for as long as possible. The result was measured with accuracy of 0.1.

Bioethical Committee

All participants were informed about procedures, risks and times of the research and signed the informed consent before initiating the research. Parents or legal guardians signed the informed consent for participants under the age of 18. The study was conducted according the guidelines of the declaration of Helsinki. The research was approved by Ethics Committee of UPJŠ (No. 1/2022).

Statistical analysis

The obtained data were processed by statistical analysis using Statistica 14.1. Based on the low quantity of the research sample ($n<30$) and the results of the assessment of the normality of the data distribution using the Shapiro-Wilk test, non-parametric mathematical and statistical characteristics and tests were chosen for further analysis. The intersexual differences were evaluated based on the results of Mann-Whitney U test at the significance level of $p<0.05$. The coefficient r was used to evaluate the effect size within the Mann-Whitney U test procedure, which was interpreted using the cut-off values as follows: $0.10 \leq r\ 0.29$ – small effect, $r = 0.30 \leq r\ 0.49$ – medium effect, $r \geq 0.50$ – large effect. The strength of association between the factors was evaluated based on the results of Spearman's rank correlation coefficient at the significance level of

$p<0.05$ and $p<0.01$. The results of the correlation coefficients were interpreted according to the scale presented by Cohen (1992): $0.10 \leq r\ 0.29$ –small effect, $r = 0.30 \leq r\ 0.49$ –medium effect, $r \geq 0.50$ –large effect.

Results

The results of general and specific muscle strength tests of girls and boys together with intersexual differences are presented in Table 2.

Table 2: Intersexual differences of general and specific muscle strength

	Boys (n=16)		Girls (n=10)		Mann-Whitney U			
	Med	QD	Med	QD	U	Z	p	r
HDDH rel	0.60	0.10	0.42	0.08	34.00	-2.42	0.02	0.47†
HDNH rel	0.50	0.09	0.41	0.10	40.00	-2.11	0.04	0.41†
BAH [s]	60.46	18.64	55.36	25.36	5.00	-3.95	<0.01	0.77‡
HB [s]	150.84	27.80	122.81	45.74	43.00	-1.95	0.05	0.38†
MFFST DH rel	0.72	0.08	0.73	0.06	79.00	-0.05	0.96	0.01
MFFST NH rel	0.67	0.06	0.72	0.08	67.00	-0.69	0.49	0.14
BAHHB [s]	24.04	7.83	24.29	15.54	78.00	-0.11	0.92	0.02
FHT [s]	28.19	13.32	35.95	14.79	79.00	-0.05	0.96	0.01

Note. HDDH: hand dynamometry for dominant hand (kg/body weight); HDNH: hand dynamometry for non-dominant hand (kg/body weight); HB: hang on bar; BAH: bent-arm hang; MFFST DH: Maximal flexor-finger strength test for dominant hand (kg/body weight); MFFST NH: Maximal flexor-finger strength test for non-dominant hand (kg/body weight); BAHHB: Bent- arm hang on hangboard; FHT: Finger hang test; Med: median; QD: quartile deviation; U: Mann Whitney U test criterion; Z: critical value for 95% confidence interval; p: statistical significance; r: effect size (0,1 – small; 0,3† – medium; 0,5‡ – large)

An analysis of general muscle strength showed statistically significant differences in the relative strength of the hand grip and muscle endurance of upper limbs in the relation to sex. In comparison to girls, boys achieved a higher level in all tests of general muscle strength. An analysis of specific muscle strength showed no statistically significant differences in relation to sex. Based on a comparison of medians we can conclude a higher level in all tests of specific muscle strength in girls compared to boys (table 2).

Based on the correlation analysis of boys muscle strength,

Table 3: Relationship between general and specific muscle strength of boys climbers

	HDDH rel	HDNH rel	BAH	HB	MFFST DH rel	MFFST NH rel	BAHHB	FHT
HDDH rel	1.00							
HDNH rel	0.90**	1.00						
BAH [s]	0.52*	0.46	1.00					
HB [s]	0.16	0.28	0.34	1.00				
MFFST DH rel	0.58*	0.57*	0.57*	-0.05	1.00			
MFFST NH rel	0.59*	0.49	0.60*	-0.18	0.82**	1.00		
BAHHB [s]	0.73**	0.64**	0.50	0.39	0.29	0.36	1.00	
FHT [s]	0.82**	0.84**	0.61*	0.34	0.59*	0.61*	0.67**	1.00

Note: HDDH: hand dynamometry for dominant hand (kg/body weight); HDNH: hand dynamometry for non-dominant hand (kg/body weight); HB: hang on bar; BAH: bent-arm hang; MFFST DH: maximal flexor-finger strength test for dominant hand (kg/body weight); MFFST NH: maximal flexor-finger strength test for non-dominant hand (kg/body weight); BAHHB: Bent-arm hang on hangboard; FHT: finger hang test; * – $p < 0.05$; ** – $p < 0.01$

Table 4: Relationship between general and specific muscle strength of girls climbers

	HDDH rel	HDNH rel	BAH	HB	MFFST DH rel	MFFST NH rel	BAHHB	FHT
HDDH rel	1.00							
HDNH rel	0.83**	1.00						
BAH [s]	0.41	0.23	1.00					
HB [s]	0.52	0.48	0.67*	1.00				
MFFST DH rel	0.29	0.17	0.76*	0.81**	1.00			
MFFST NH rel	0.15	0.16	0.69*	0.61	0.84**	1.00		
BAHHB [s]	0.56	0.50	0.87**	0.90**	0.85**	0.79**	1.00	
FHT [s]	0.51	0.42	0.71*	0.85**	0.79**	0.82**	0.90**	1.00

Note: HDDH: hand dynamometry for dominant hand (kg/body weight); HDNH: hand dynamometry for non-dominant hand (kg/body weight); HB: hang on bar; BAH: bent-arm hang; MFFST DH: maximal flexor-finger strength test for dominant hand (kg/body weight); MFFST NH: maximal flexor-finger strength test for non-dominant hand (kg/body weight); BAHHB: Bent-arm hang on hangboard; FHT: finger hang test; * – $p < 0.05$; ** – $p < 0.01$

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we can conclude a statistically significant relationship between the relative strength of the hand grip and maximum finger strength and also strength endurance of back and forearm muscles. It is also possible to observe the occurrence of dependence between muscle endurance in bent-arm hang and maximum finger strength and strength endurance of forearm muscles on hangboard.

Based on the correlation analysis of girls muscle strength, we can conclude a statistically significant relationship between general and specific strength endurance of back and forearm muscles. It is also possible to observe the highest occurrence of dependence between specific strength of fingers and strength endurance of back and forearm muscles on hangboard (table 4).

Discussion

This study aimed to assess gender-specific relations between specific and general muscle strength of youth boulderers and their intersexual differences. Results did reveal differences in studies variables between genders in general muscle strength in favor of boys, who had higher level of general muscle strength in all tests, this may be due to the higher decimal age of the boys, which was 14 years. At this age, there is a sharp increase in muscle strength of boys (Armstrong, Van Mechelen, Ba De Ste Croix 2023). At around 15 years old, many boys are in the midst of or completing puberty, leading to a significant increase in testosterone levels. This hormone promotes muscle growth, especially in the upper body, leading to greater muscle mass and strength development (Rogol et al. 2000; Espen et al. 2011) .

On the opposite, results did not reveal statistically significant differences in studies variables between genders in specific muscle strength, which can be cause due to the higher sports age of the girls. Another reason may be the nature of the structure of sport climbing performance which necessitates the development of specific abilities in comparable manner in both sexes (Vrdoliak, Gilic, Kontic 2022). Potential explanation is the manner in which athletes are selected for participation in sporting activities. In Slovakia, data from the Slovak Mountaineering Association indicate that more girls than boys participated in children's and youth climbing competitions last year. This is related to the observed decline in participants between the U14 and U16 age categories for boys. A similar trend was also confirmed in the research of Emmonds et al. (2021), who also recorded a significant decline in participation for youth males from U14 to U18 in most sports.

The results of correlation analysis of boys muscle strength proved statistically significant relationship between the relative strength of the hand grip and maximum finger strength and also strength endurance of back and forearm muscles, which are important predictors of climbing performance (Baláš et al. 2012; Ginszt et al. 2023). This is also pointed out by the research Kalayci and Baskan (2023) who examined on 52 sports climbers the relationship of anaerobic power, upper extremity strength and competition performances. Significant relationships were found between upper extremity strength values and result of the competition. The factors affecting climbing performance were explained as 65.22% finger and hand grip strength values.

Correlation analysis for girls showed us different results. It was shown that for girls, the bent-arm hang test has a statistically significant relationship with all specific tests, which may mean that the strength of the shoulder girdle may be more important for girls in relation to climbing performance, which was also confirmed in the research of Kodejška and Baláš (2016), who focused on evaluating relationships between the rock climbing performance and the strength of finger flexors and shoulder girdle muscles in female rock climbers.

The hang-on bar test is influenced by the performance of hand dynamometry, as evidenced by the lower correlations observed in boys. This is due to the fact that boys perform better in hand dynamometry, which results in a lower intensity of the hang-on bar test relative to their maximal voluntary strength. Consequently, the hang-on bar test has a greater endurance component in boys than in girls. This can also suggest that the importance of general strength in climbing is overstated, as there are no gender differences in sport-specific tests. Girls compensate for their longer sport-specific age, but the correlations between MFFST and FHT are lower in boys (R=0.59-0.61) than in girls (R =0.79-0.82). Consequently, despite the fact that boys perform the same in MFFST, THT contains more endurance components for boys than for girls, whereas girls have more strength components.

It should be noted that our study has some limitations. Research focused only on boulderes not for lead or speed climbers, therefore it would be appropriate to expand the research to include these two sports disciplines in the future. There was also a certain inhomogeneity of sports age between boys and girls, which could affect the monitored strength parameters. Most research focuses on the adult population, research dealing with youth is rare, so it was difficult to compare the performance level of other youth climbers. But on the other hand, this is the uniqueness of our study together with fact that that is one of the first research on climbers from Slovakia.

Conclusions

Climbers benefit from a combination of general and specific strengths, which are tailored to meet the demands of climbing. General strength constitutes the foundation of overall athleticism, whereas specific strengths directly impact climbing performance by addressing the distinctive physical challenges inherent to the sport. This study assess the intersexual differences and gender-specific relations between specific and general muscle strength of youth boulderers. Results did reveal statistically significant differences in studies variables between genders in general muscle strength in favour of boys. On the other side there are non- existing or negligible gender differences of specific muscle strength which can be caused by selected research sample. Correlations of specific and general muscle strength showed that there were more evident and stronger relationship between specific and general muscle strength among males than in females. In order to design a training programme with the specific aim of developing general and specific muscle strength, it is first necessary to highlight the methods that are typically used to assess training levels. An efficacious training programme for climbers should comprise elements that cultivate both types of strength, thereby ensuring comprehensive development and enhanced climbing ability. The present study may suggest a modification of the training process in sport climbing based on gender, which may have an impact on the development of strength skills among boulderers.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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