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Original research article

THE STRENGTH STRUCTURE OF SPORT CLIMBERS

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Abstract. *The aim of this paper was to determine the structure of the strength of sport climbers. The study was conducted on 32 sports climbing competitors aged 27.47 ± 4.76, competing at the national and international level of competition. Strength structure was determined by using 18 measuring instruments for strength evaluation (9 for the evaluation of general and 9 for the evaluation of specific strength). In the hypothetical area of strength, three significant factors that explained 85.83% of the common variance of the whole system were isolated: the factor of general and specific static strength (with a common variance of 43.53%), the factor of general and specific repetitive strength (with a common variance of 21.23%), and the factor of general and specific explosive strength (with a common variance of 21.07%). In this way, the sports climbers strength area is represented as three-dimensional.*

Key words: *general strength, specific strength, sports climbing.*

INTRODUCTION

Sports climbing today is a complex sport, complete with its own vocabulary and equipment that have come about over decades of experimentation. It has, for many years, been one of the fastest growing leisure activities, involving millions of people worldwide (Creasey & al., 1999; Wright, Royle, & Marshall, 2001; Mihailov, 2008; Davis, 2004). The popularity of this sport has led to the increased interest of scientists from around the world for research issues in sport climbing.

According to sports classification, sports climbing belongs to a group of combined (complex) sports (Stanković, 2009; Stanković, Joksimović, & Aleksandrović, 2011).

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They are characterized by a high variety of movements in compensated fatigue and changing intensity of work. The immanent characteristic of these sports is a changeable competition situation and a need to preserve the high level of working capacity in compensated fatigue conditions. These types of sports include features of organization of movement activities and energy provision mostly in acyclic and cyclic sports. Bearing in mind the changing intensity of the competitions' activity, the alteration of high movement activities and total rest, the work energy of muscles has an aerobic-anaerobic feature and a specific weight of the glycolytic reaction (Verhošanski, Šestakov, Novikov, & Nićin, 1992).

Performing in the vertical plane requires physical capabilities such as strength, power, and endurance. It also demands the development of technical skills such as balance and economic movement while gripping and stepping in an infinite variety of ways, positions, and angles. Most importantly, the inherent stress of climbing away from the safety of the ground requires acute control of your thoughts, focus, anxiety, and fears. In aggregate, the above factors dovetail into what may be one of the more complex sporting activities on this third rock from the sun (Horst, 2003).

"Strength, or muscular strength, is the ability to generate maximum maximorum external force" (Zatsiorsky & Kraemer, 2006). In the world of sports, most disciplines require some degree of both strength and motor skills for the athlete to be successful (Newton & Kraemer, 1994; Jensen, Marstrand, & Nielsen, 2005; Rahimi & Bephur, 2005).

Since athletic performance is strongly dependent on choosing relevant training modalities, coaches and athletes need to know what 'winning' characteristics they should be training (Binney & Cochrane, 2003a). Some researchers tried to use biomechanical analyses to predict success in sports climbing (Quaine, Martin, & Blanchi, 1997a,b; Binney & Cochrane, 2003b). Other researchers connected the success in sport climbing to the physiological responses of the body in sport climbing (Booth, Marino, Hill, & Gwin, 1999; Mermier, Janot, Parker, & Swan, 2000; Davis, 2004; Sheel, 2004; Macleod & al., 2007).

Strength is a basic physical ability most frequently studied and most valued in body exercise, especially in sport (Stanković, Joksimović, Raković, Michailov, & Piršl, 2009). Considering strength, both general and specific strength has a high prediction of success in sport climbing (Stanković, 2009; Stanković et al., 2011), along with climbing specific forearm endurance (Binney et al., 2003a), while muscular endurance and high upper body power are also important (Watts, 2004), and forearm musculature concentric wrist flexion (Schweizer & Furrer, 2007).

Considering that strength is one of the key factors of success in sports climbing, the aim of this study is to determine the strength structure of sport climbers.

THE METHOD

The sample of participants for this research was drawn from a population of sports climbing competitors, 32 of them, all of whom competed at the federal and international level. The sample consisted of competitors who voluntarily took part in the *Naissus route climbing challenge 03* Balkan competition held in May 2009. The average height of the sports climbers was 179.94 ± 5.19 cm, body mass 69.72 ± 6.53 kg and body mass index 21.53 ± 1.84. The participants average age was around 27.47 ± 4.76, with an average climbing experience of 7.02 ± 4.34 years.

In this study, the following tests were applied to estimate the strength of the sport climbers:

- General explosive strength tests including: the standing long jump (SDIM), throwing a medicine ball from a lying position (BMLP) and push-ups for 15 seconds (S15S);
- Specific explosive strength tests included: maximal reach with the left hand (MDLR), maximal reach with the right hand (MDDR) and maximal reach with both hands (MDOR);
- General repetitive strength tests included: pull-ups (ZGIB), sit-ups (DTŠK) and back extensions (ISTR);
- Specific repetitive strength tests included: pull-ups with two fingers (ZG2P), horizontal pull-ups on the left hand (HZLR) and horizontal pull-ups on the right hand (HZDR);
- General static strength tests included: hanging pull-ups (VUZG), straight-arm hangs with a wide grip (IVŠI) and hanging on the dominant arm (IVDR);
- Specific static strength tests included: Block under a 90˚ angle (BL90), Block under a 90˚ angle on the left hand (B90L) and Block under a 90˚ angle on the right hand (B90D).

Conditions of measurement and the description of the tests

A plan of variable measurement was implemented by means of work stations in a circle so that bigger muscle groups and different functional mechanisms could be engaged alternatively in order to avoid the influence of one test on the other. Apart from that, enough time to rest between the tests was provided, so as to diminish the effect of previous testing.

The applied set of tests of general power was taken from the research Kurelić et al. (1975). It has been used numerous times in basic experimental research and has an appropriate level of metric characteristics in explaining the tested motor dimensions. The metric characteristics of specific strength tests of sport climbers were determined in the work of Stankovic et al. (2009).

Statistical analyses

In order to determine the structure of strength of sport climbers, the following statistical operations are applied:

1) Descriptive statistics. The results of this research were processed so as to get the information on central and dispersion parameters for all the manifest variables: the number of participants (N), mean value (Mean), minimum (Min) and maximum (Max) numeric results, range (Range), standard deviation (Std.Dev.) and standard error for the mean value (Error).

2) Discrimination of the measurement in this research was performed by two procedures: Skewness (Skew.) which explains the symmetry of the results distribution around the arithmetic means and Kurtosis (Kurt.) which denotes length or flatness of the distribution.

3) Strength structure was processed with the help of factor analysis used to calculate the characteristic roots and explained parts of the common variance, structure matrix and factor inter-correlation matrix.

RESULTS AND INTERPRETATION

Table 1 Basic statistical parameters of general and specific strength

Variables	N	Mean	Min	Max	Range	Std.Dev.	Error	Skew.	Kurt.
SDIM	32	238.16	210.0	290.0	80.0	19.91	3.520	1.0923	1.1029
BMLP	32	11.28	9.5	13.5	4.0	1.13	0.199	0.1945	–0.9868
S15S	32	18.03	14.0	25.0	11.0	2.75	0.487	0.4699	–0.1120
MDLR	32	72.00	38.0	102.0	64.0	18.64	3.295	–0.2036	–1.1806
MDDR	32	69.66	35.0	97.0	62.0	18.61	3.289	–0.2607	–1.0973
MDOR	32	56.59	28.0	77.0	49.0	14.66	2.591	–0.4615	–1.0103
ZGIB	32	19.72	10.0	30.0	20.0	5.80	1.025	0.1590	–1.2100
DTŠK	32	83.78	35.0	250.0	215.0	42.27	7.472	2.0684	6.8508
ISTR	32	55.25	25.0	152.0	127.0	26.71	4.722	1.8181	4.5537
ZG2P	32	12.91	7.0	20.0	13.0	3.58	0.632	0.0952	–0.9661
HZLR	32	14.03	3.0	23.0	20.0	4.82	0.851	–0.2090	–0.5267
HZDR	32	14.78	3.0	25.0	22.0	5.18	0.916	–0.0983	–0.2646
VUZG	32	50.23	25.3	80.8	55.5	19.44	3.437	0.1981	–1.5696
IVŠI	32	51.30	15.5	90.5	75.0	24.59	4.347	0.1254	–1.4484
IVDR	32	23.81	8.3	45.0	36.7	11.04	1.951	0.1265	–1.0491
BL90	32	52.30	15.4	100.3	84.9	27.08	4.788	0.1540	–1.2884
B90L	32	8.18	1.2	18.6	17.4	5.95	1.051	0.2865	–1.5479
B90D	32	9.09	1.3	18.8	17.5	6.20	1.096	0.1700	–1.6284

By analyzing Table 1. which shows the basic statistical parameters of the general and specific strength of sports climbers, it can be noticed that all the tests have a good discrimination because their standard deviation is contained approximately 3 to 5 times within the range. From the Skewness it can be noticed that there is normal symmetry of distribution around the arithmetic means in most tests, except for the tests of the standing long jump, sit-ups and back extensions where the results are more right-handed, relative to the arithmetic mean - there are better results (the standing long jump was slightly above the threshold of +1). This means that these tests (SDIM, DTŠK and ISTR) were too easy for this sample of participants. The Kurtosis however showed that the results for the majority of variables are scattered (platikurtic distribution of the data), except for the variables of the standing long jump and back extensions, where the results were compressed (leptokurtic distribution). This does not come as a surprise since the competitors were of different ages, climbing experience and levels of training fitness.

Table 2 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.815
Bartlett's Test of Sphericity	Approx. Chi-Square	1071.508
	df	153
	Sig.	0.000

Since the Kaiser-Meyer-Olkin Measure of Sampling Adequacy is higher than 0.6 (0.815) and Bartlett's Test of Sphericity is significant (0.000), as shown in Table 2, the data was analyzed further.

Table 3 Isolated factors (rotation sums of squared loadings)

	Eigenvalue	% Total variance	Cumulative %
1	7.836	43.533	43.533
2	3.821	21.226	64.759
3	3.793	21.073	85.832

Table 3. shows the isolated factors of the general and specific strength of sports climbers after the varimax transformation. Three significant factors was isolated that explained 85.83% of the common variance of the whole system (factor I with a value of 7.84 and common variance of 43.53%, factor II with a value of 3.82 and a common variance of 21.23%, and factor III with a value of 3.79 and common variance of 21.07%).

Table 4. The factor structure

Variables	Varimax normalized		
	Factor 1	Factor 2	Factor 3
SDIM	0.2303	0.0349	**0.9047**
BMLP	0.1814	0.3190	**0.7973**
S15S	0.4386	0.2940	**0.5150**
MDLR	0.6527	0.1343	0.6762
MDDR	0.6324	0.1260	**0.6875**
MDOR	**0.6765**	0.2336	0.5711
ZGIB	0.5534	**0.7771**	0.1167
DTŠK	0.1843	**0.6283**	0.4470
ISTR	–0.2170	**0.7068**	0.3694
ZG2P	**0.7117**	0.5754	0.2662
HZLR	0.4688	**0.8438**	0.0380
HZDR	0.4810	**0.8239**	0.0279
VUZG	**0.9117**	0.2150	0.2377
IVŠI	**0.9188**	0.2274	0.2359
IVDR	**0.8747**	0.2302	0.2995
BL90	**0.9107**	0.2318	0.2658
B90L	**0.9041**	0.2449	0.2476
B90D	**0.9178**	0.2387	0.2478

Table 4. represents the matrix of structure that contains the projections of the variables on the factors (correlations between variables and factors) after the varimax transformation. The interpretation of the three-dimensional model, limited by 18 manifest variables, comes down to the following:

The first factor in the Varimax transformation is best defined by the tests B90D, IVŠI, VUZG, BL90, B90L and IVDR. All these tests belong to the hypothetical factor responsible for the evaluation of static strength (general and specific). The above-mentioned tests are uniquely complex, i.e., do not share a variance with some other factors. With this factor we find the somewhat less related tests ZG2P and MDOR. However, they have a complex character, because they are almost equally involved in the formation of a third, or second factor. A common manifested feature of all the tests of unique complexity is the ability to maintain higher isometric muscle contractions which keep the body in a certain posture so as not to manifest strength on a certain route, but during its action. This latent dimension would be most suitable for equation with the hypothetical dimension of general and specific static strength.

The second factor in the Varimax transformation is best defined by the tests: HZLR HZDR ZGIB, ISTR and DTŠK but also by the ZG2P test. All these tests belong to the hypothetical factor responsible for the evaluation of repetitive strength (general and specific). Tests HZLR HZDR, ISTR and DTŠK have unique complexity, i.e., do not share a variance with some other factors, while tests ZGIB and ZG2P participate in the formation of the first factor. A common manifest feature of all these tests, of a unique as well as complex character, was the dynamic strength that generally has a cyclic nature, whose manifestation is characterized by the alternation of the tension and relaxation of muscles. This latent dimension would be most suitable for equation with the hypothetical dimension of general and specific repetitive strength.

The third factor in the Varimax transformation is best defined by the tests: SDIM, BMLP, MDDR, MDLR and S15S, but also the MDOR test. All these tests belong to the hypothetical factor responsible for the evaluation of explosive strength (general and specific). Tests SDIM, BMLP and S15S have unique complexity, i.e., do not share a variance with some other factors, while tests MDLR, MDDR and MDOR participate in the formation of the first factor. A common manifest feature of all these tests, of a unique as well as complex character, is the ability to manifest maximum power for a maximally short period of time. This latent dimension would be most suitable for equation with the hypothetical dimension of general and specific explosive strength.

DISCUSSION

Perhaps no sport can match rock climbing for its dramatic increase in the mean level of performance of its participants in recent years. Today's average climber is capable of a standard that few climbers dreamed of achieving in the mid-1970s. The reasons for these incredible improvements include sticky-soled shoes, sport-climbing tactics, and, more than anything else, the advent of climbing gyms and a growing focus on sport-specific strength training (Horst, 2003).

Considering the fact that in previous studies it was proven that strength, and especially specific strength (Binney et al., 2003a; Horst, 2003; Watts, 2004; Schweizer et al., 2007; Stanković, 2009; Stanković et al., 2011) is an important factor for success in sport climbing (and probably is the most important factor), in this research we performed a division of the strength of sport climbers based on action criteria. According to this division, strength was separated into general and specific static strength, general and specific repetitive strength and general and specific explosive strength. Such research was not carried out so far on the population of sport climbers, probably due to the later appearance and popularization of this sport.

According to Nicin (2000), this strength division was confirmed in the research of many authors in the period from 1949 to 1975. The results of this study confirm the ones from previous research and the strength division based on action criteria into static, repetitive and explosive strength (Nićin, 2000; Stojiljković, 2003; Herodek, 2006)

CONCLUSION

In the hypothetical area of strength, three significant factors that explained 85.83% of the common variance of the whole system were isolated: the factor of general and specific static strength with a common variance of 43.53%, the factor of general and specific repetitive strength, with a common variance of 21.23%, and factor of general and specific explosive strength, with a common variance of 21.07%. In this way, the strength of sports climbers is represented as three-dimensional. The factor of general and specific static strength is defined by the following tests: block under a 90˚ angle on the right hand, hanging pull-ups with a wide grip, hanging pull-ups, block under a 90˚ angle, block under a 90˚ angle on the left hand and hanging on the dominant arm. The second factor (factor of general and specific repetitive strength) is defined by the following tests: horizontal pull-ups on the left hand, horizontal pull-ups on the right hand, hanging pull-ups with a wide grip, back extensions and sit-ups. The factor of general and specific explosive strength is defined by the following tests: the standing long jump, throwing a medicine ball from a lying position, maximal reach with the right hand, maximal reach with the left hand and push-ups for 15 seconds.

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STRUKTURA SNAGE SPORTSKIH PENJAČA

Cilj ovog rada bio je da se utvrdi struktura snage sportskih penjača. Istraživanje je sprovedeno na 32 takmičara u sportskom penjanju uzrasta 27.47 ± 4.76 godina koji se takmiče na nacionalnom i međunarodnom nivou takmičenja. Struktura snage određena je korišćenjem 18 mernih instrumenata za procenu snage (9 za procenu opšte i 9 za procenu specifične snage). U hipotetskom prostoru snage izolovana su tri faktora: faktor opšte i specifične statičke snage, faktor opšte i specifične eksplozivne snage i faktor opšte i specifične repetitivne snage. Na ovaj način je prostor snage sportskih penjača predstavljen kao trodimenzionalan.

Ključne reči: *opšta snaga, specifična snaga, sportsko penjanje*