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RELATION AND INFLUENCES OF SPORT CLIMBERS' SPECIFIC STRENGTH ON SUCCESS IN SPORT CLIMBING

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ABSTRACT

The aim of this research was to determine relations to, and influences of the specific strength of sport climbers on success in sport climbing. Research was conducted on a sample of sport climbers (N=32), participants in the Balkan championships "Naissus Route Climbing Challenge 03", competing on national and international level, by the application of nine tests for the estimation of sport climbers' specific strength and three variables for the estimation of success in sport climbing. Relations were determined by means of canonical correlation analysis and the influences by means of a regression analysis. The results of the research show that success in sport climbing depends on specific strength, mostly specific static strength. All variables have statistically significant projections on the canonic factor, most of all variables of specific static strength – block under 90˚ angle (BL90), block under 90˚ angle on left hand (B90L) and block under 90˚ angle on right hand (B90R) and variables of the situational-motor explosive strength – maximal reach with left hand (MRLH), maximal reach with right hand (MRRH) and maximal reach with both hands (MRBH) and pull-ups with two fingers (PU2F). Also, it can be concluded that specific strength significantly influences the success in all three criteria – the most difficult climbed route up to now (MDCR), the most difficult climbed route this season (MDDS) and competition standings (COST). However, none of the variables individually significantly influenced the most difficult climbed route up to now (MDCR); two variables – maximal reach with right hand (MRRH) and block under 90˚ angle (BL90) – influenced the most difficult route climbed this season (MDDS); and two variables for the estimation of static strength – block under 90˚ angle (BL90) and block under 90˚ angle on left hand (B90L) – influenced competition standings (COST). The obtained results can be utilised for the selection and direction of young talent towards sport climbing.

Key words: Specific strength; Sport climbing; Competition standing

INTRODUCTION

Sport climbing today is a complex sport, complete with its own vocabulary and equipment that have come about over decades of experimentation. For many years it has been one of the fastest-growing leisure activities, involving millions of people worldwide (Creasey *et al*., 1999). For example, according to the annual report in the Recreation Participation Study by the Outdoor Industry Association (2002), the United States of America (USA) can boast over 8.8 million climbers over the age of 16 years (i.e. 4.1% of the USA's population) and in Great

Britain the number of climbers increased by 40% in the period between 1989 and 1993 (Wright *et al.*, 2001; Davis, 2004; Mihailov, 2008). The diverse pursuits that make up the forms of the sport all require dedication from their participants and tend to evoke admiration from, and inspiration in, others (Davis, 2004).

According to the sport classification, sport climbing belongs to a group of combined (complex) sport. They are characterised by a large variety of movements in compensated fatigue and changing intensity of work (Verhosanski *et al.*, 1992). An important characteristic of these sport is a changeable competition situation and a need to preserve a high level of working capacity in compensated fatigue conditions. Acyclic and cyclic types of sport include features of organisation of movement activities and energy provision. Bearing in mind the changing intensity of the competitions' activity, alteration of high movement activities and total rest, the energy work of muscles has aerobic-anaerobic features and a specific weight of glycolitic reaction (Verhosanski *et al.*, 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 important, the inherent stress of climbing away from the safety of the ground requires acute control of one's thoughts, focus, anxiety and fears. In total, the above factors combine into what may be one of the most complex sporting activities on this "third rock from the sun" (Horst, 2003).

All climbing disciplines demand strength, endurance and skills acquired during long systematic training. Physical preparation for sport climbing implies increased volume and specificity of the training as progression towards the elite athlete's form. Since most sport climbers do not follow any expert training plan (Twight & Martin, 1999) but utilize their 'feelings', it is assumed that more advanced climbing formula could be obtained by the administration of systematic and documented sport climbing principles. These include frequency, intensity, duration and types of training (Wilmore & Costill, 1999), which are to be selected considering the specific motor abilities of each climber.

"Strength, or muscular strength, is the ability to generate maximum external force" (Zatsiorski & Kraemer, 2006: 21). In the world of sport most disciplines require some degree of both strength and motor skill for the athlete to be successful (Jensen *et al.*, 2005; Rahimi & Bephur, 2005).

Specific motor abilities are acquired in life and specifically in some sport and are the result of specific training, i.e. particular motor training. During the training process in a specific sport basic motor abilities are modified according to the demands of the given sport. These are basics used to build on specific motor abilities. Success in sport largely depends on numerous specific motor and other abilities (Nićin, 2000).

Rock climbing movements require following a pattern that mostly exerts severe pressure on the musculoskeletal system of the upper limbs. Total body weight is placed on the hand and one finger or more, many times during the performance. Active limbs, such as the hand and

fingers in particular, acting as support and connection points between a climber's body and the wall, are susceptible to movement injuries (Shahram *et al.*, 2007).

There is a lack of research in the area of success prediction in sport climbing regarding general and specific strength (Stanković, 2009). Since fitness depends exclusively on the choice of adequate training models, athletes should be aware of the winning abilities they can develop (Binney & Cochrane, 2003a). Some researchers tried to use biomechanical analyses to predict success in sport climbing (Quaine *et al.*, 1997a,b; Binney & Cochrane, 2003b). However, a body of research on success in sport climbing is connected with physiological responses of the body during this sport (Booth *et al.*, 1999; Meimer *et al.*, 2000; Davis, 2004; Sheel, 2004; Macleod *et al.*, 2007). As for strength, high prediction values for the success in sport climbing are attributed to a specific climbing endurance in the lower-arm muscle strength (Binney & Cochrane, 2003a). The following factors have also been researched: muscle endurance and strength of the upper body (Watts, 2004); and relative strength and concentric flexion of hand wrist muscles (Schweizer & Furrer, 2007).

Bearing in mind that success in sport depends on specific motor abilities, the aim of this research was to determine relations to and influences of the specific strength of sport climbers on success in sport climbing.

METHOD

Sample of subjects

The sample (N=32) for this research was drawn from a population of sport climbing competitors, all competing on federal and international level. The sample comprised voluntary competitors who took part in the "Naissus route climbing challenge 03", a Balkan competition held in May 2009.

The average height of sport climbers was 179.94 ± 5.19 cm, body mass 69.72 ± 6.53 kg and body mass index 21.53 ± 1.84. The research sample was around 27.47 ± 4.76 years of age, with an average climbing experience of 7.02 ± 4.34 years.

Variable sample

Following specific strength tests, the climbers were divided into three groups: specific explosive strength, specific repetitive strength and specific static strength tests (Stanković, 2009). Specific explosive strength tests were: maximal reach with left hand (MRLH); maximal reach with right hand (MRRH); and maximal reach with both hands (MRBH). Specific repetitive strength tests were: pull-ups with two fingers (PU2F); horizontal pull-ups on left hand (HPLH); and horizontal pull-ups on right hand (HPRH). Specific static strength tests were: block under 90˚ angle (BL90); block under 90˚ angle on left hand (B90L); and block under 90˚ angle on right hand (B90R). Success in sport climbing was assessed by means of three variables (Stanković, 2009): the most difficult route climbed up to now (MDCR); the most difficult route climbed this season (MDDS); and competition standings (COST).

The most difficult route climbed up to now is a grade given for the most difficult route climbed by the subject in his/her overall climbing career. The most difficult route climbed this season is a grade given for the most difficult route climbed by the subject in that season (up to the competition date). This grade is displayed in numerical value according to the international assessment table for route scoring (Table 1). Competition standing is a sum of the best 10 routes a competitor climbed in three days of the competition. In case a climber does not climb 10 routes all climbed routes are graded.

TABLE 1. **GRADING SYSTEM OF WORLD RATING LIST OF NATURAL ROCK CLIMBING**[1]

GRADE	POINTS	BONUS POINTS
X+ (8b+)	1150	On Sight (O.S.) – points are awarded for 3 grades more - 5 points (+145 points)
X (8b)	1100	
X- (8a+)	1050	Flash (F) – points are awarded for 1 grade more +3 points (+53 points)
IX+/X- (8a)	1000	
IX+ (7c+)	950	Second Go (2Go) – one assigns +2 points
IX (7c)	900	First ascent (F.A.) – one assigns +10 points
IX- (7b+)	850	NOTE: At the start of the competition a list of unclimbed routes is given (projects) that could be climbed. (F.A.)
VIII+/IX- (7b)	800	
VIII+ (7a+)	750	
VIII (7a)	700	
VIII- (6c+)	650	
VII+/VIII- (6c)	600	
VII+ (6b+)	550	
VII (6b)	500	
VIII- (6a+)	450	
VI+/VII- (6a)	400	
VI+ (5c+)	350	
VI (5c)	300	
VI-	250	
V+	200	
V	150	

DATA ANALYSIS

Results of this research were processed in order to obtain information on the central and dispersion parameters for all manifest variables: number of subjects (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).

Discrimination of the measurement in this research was performed by two procedures:

[1]Grade conversion (2008)

- Skewness (Skew.) that explains the symmetry of the distribution of results around the arithmetic mean. If it is normal, the skewness value will be zero. A great number of weak results will be represented by a negative sign and a great number of good results will be represented by a positive sign. Skewness values range from minus three to plus three. All results over 1.00 indicate too light a task and all results below minus one denote too difficult a task.
- Kurtosis (Kurt.) denotes length or flatness of the distribution. When the observed distribution is not statistically different from the normal one (mesokurtic distribution), the value of this test is about 2.75. If the result of Kurtosis is remarkably higher than 2.75 (leptokurtic distribution) it means the results are very close and if the result is smaller than 2.75 (platikurtic distribution) it means the results are highly scattered.

To determine the relation of specific strength to success in sport climbing a canonic correlation analysis was used. This analysis explains the relation structure for the two sets of variables. The following was computed:

- size of canonic correlation (Can. R), which denotes maximal correlation between the two sets of predicting variables and a set of criterion variables;
- canonic power of determination (Can. R^2), which represents a percentage of the common variability of the researched area;
- Bartlett Lambda test (Chi-sqr), which represents a testing of the statistical significance of the canonic correlation coefficient;
- degree of freedom (df);
- degree of significance (p) representing a level of the significance of canonic factor pairs; and
- in the column (Root) a structure of isolated canonic factors was shown.

To determine the influence of the predicting variables (tests of specific strength) on each criterion variable a regression analysis was used. It contained the following parameters: coefficient of correlation (R); coefficient of the partial correlation (PART–R); standardised regression coefficient (BETA); vector of the standardised regression coefficient (t); significance of beta coefficient (p-level); coefficient of the multiple correlation (R); coefficient of the determination (R^2); and the level of the significance of regression connection on a multivariate level (p). Raw data were processed by means of the Statistica 8.0 software package. Statistical significance was determined at a level of $p<0.05$.

RESULTS AND DISCUSSION

By analysing Table 2, which depicts basic statistical parameters of the specific strength of sport climbers, it can be seen that the tests of specific explosive strength (MRLH, MRRH and MRBH), as well as the tests of specific repetitive strength (PU2F, HPLH and HPRH) showed excellent discrimination for their standard deviation was about 3 to 3.5 times smaller than their mean value. On the other hand, somewhat weaker variability was shown by variables for the estimation of specific static strength (BL90, B90L and B90R) because their standard deviation was about 2 to 2.5 times smaller than their mean value. From their Skewness (Skew.) it could be seen that there was a normal symmetry of distribution around the arithmetic mean in all tests. However, kurtosis showed that results in all variables were

scattered (platikurtic distribution of data). This did not come as a surprise since the competitors were of different ages, climbing experience and level of fitness.

TABLE 2: **BASIC STATISTICAL PARAMETER-PREDICTING VARIABLES**

Variables	N	Mean	Min	Max	Range	SD	Error	Skew	Kurt
MRLH	32.000	72.000	38.000	102.000	64.000	18.639	3.295	-0.204	-1.181
MRRH	32.000	69.656	35.000	97.000	62.000	18.606	3.289	-0.261	-1.097
MRBH	32.000	56.594	28.000	77.000	49.000	14.659	2.591	-0.462	-1.010
PU2F	32.000	12.906	7.000	20.000	13.000	3.577	0.632	0.095	-0.966
HPLH	32.000	14.031	3.000	23.000	20.000	4.816	0.851	-0.209	-0.527
HPRH	32.000	14.781	3.000	25.000	22.000	5.179	0.916	-0.098	-0.265
BL90	32.000	52.303	15.400	100.300	84.900	27.082	4.788	0.154	-1.288
B90L	32.000	8.181	1.200	18.600	17.400	5.947	1.051	0.286	-1.548
B90R	32.000	9.094	1.300	18.800	17.500	6.201	1.096	0.170	-1.628

As expected (Table 3) canonic correlation analysis showed the existence of only one statistically significant canonical factor, i.e. one significant correlation of the variable for the estimation of specific strength and success in sport climbing (second and third factors were not statistically significant). That one significant function explained 94% of the total variability of these two sets of variables, which was considered a highly significant level of correlation. Significance of correlation is p = 0.000000.

TABLE 3: **CANONIC FACTORS OF SPECIFIC STRENGTH AND SUCCESS IN SPORT CLIMBING AND THEIR SIGNIFICANCE**

	Canonical-R	Canonicl-R-sqr.	Chi-sqr.	df	P
1	**0.970**	**0.941**	**85.404**	**27.000**	**0.000000**
2	0.638	0.406	15.861	16.000	0.463000
3	0.344	0.118	03.077	07.000	0.878000

Table 4 depicts coefficients of correlations of the manifest variables in both sets (specific strength and success in sport climbing) with the isolated canonic function.

In the area of specific strength function was mostly defined by the variables of specific static strength (BL90, B90L and B90R) with coefficients over 0.930 and variables of situational-motor explosive strength (MRLH, MRRH and MRBH) and pull-ups with two fingers (PU2F) with coefficients over 0.840. Also, all other variables showed statistically significant projections on canonic factor, but with somewhat lower, yet high values of the coefficient of correlation. This factor could be defined as a factor of specific strength.

In the other set of data function was defined by all variables for the estimation of success in sport climbing. The biggest projection on canonic factor had a variable competition standing (COST = 0.985), followed by the most difficult route climbed this season (MDDS = 0.886) and ultimately the most difficult route climbed up to that moment (MDCR = 0.775).

TABLE 4: **FACTOR STRUCTURE OF SPECIFIC STRENGTH AND SUCCESS IN SPORT CLIMBING**

Variables	Root 1	Variables	Root 1
MRLH	**0.854**	**MDCR**	**0.775**
MRRH	**0.848**	**MDDS**	**0.886**
MRBH	**0.844**	**COST**	**0.985**
PU2F	**0.851**		
HPLH	**0.591**		
HPRH	**0.586**		
BL90	**0.978**		
B90L	**0.932**		
B90R	**0.948**		

Analysis of the corresponding canonic functions points to the assumption that success in sport climbing depends on specific strength, mostly on specific static strength. Since all measures of specific strength were in direct proportion with the measures of success in sport climbing, it could be concluded that the subjects with greater specific strength will be more successful in sport climbing.

Relatedness of the whole system of specific strength and the most difficult route climbed up to now (MDCR), i.e. coefficient of multiple correlation, was 0.82 ($R = 0.825$), which explains common variability between the system and criterion variable with about 68% ($R^2 = 0.681$). When explaining the total variability of the most difficult route climbed up to now the remaining 32% could be ascribed to other characteristics and abilities of the subjects, which were not taken into account (other motor abilities, morphological characteristics, etc.) and the testing conditions. These results provided a statistically significant explanation of the criterion variable by means of the system of specific strength ($p < 0.001$), thus it could be concluded that the system of specific strength had a statistically significant influence on the most difficult route climbed up to now (Table 5).

By analysing single regression coefficients it could be concluded that none of the coefficients was statistically significantly related to the criterion variable MDCR.

TABLE 5: **REGRESSION ANALYSIS OF VARIABLE MDCR BY MEANS OF THE SYSTEM OF VARIABLES OF SPECIFIC STRENGTH**

Variables	R	Part-R	Beta	Std.Err. of Beta	t(13)	p-level
MRLH	0.678	-0.237	-1.469	1.282	-1.146	0.264
MRRH	0.692	0.342	2.134	1.249	1.709	0.102
MRBH	0.666	-0.157	-0.418	0.559	-0.747	0.463
PU2F	0.742	-0.005	-0.011	0.424	-0.026	0.980
HPLH	0.591	0.137	0.528	0.811	0.651	0.522
HPRH	0.574	-0.040	-0.150	0.810	-0.186	0.854
BL90	0.718	0.246	0.749	0.630	1.190	0.247
B90L	0.679	0.118	0.784	1.410	0.556	0.584
B90R	0.680	-0.162	-1.191	1.548	-0.769	0.450
R = 0.825	**$R^2 = 0.681$**	**F(9,22) = 5.219**		**p < 0.001**		

By analysing Table 6, showing the results of relatedness of the system of specific strength and the most difficult route climbed this season, it could be said that there was a statistically

significant correlation of the system on a multivariate level $p < 0.000$. This explains the high coefficient of multiple correlation $R = 0.908$, as well as a coefficient of determination $R^2 = 0.825$, which explains the correlation of the whole system of motor abilities and criterion variables with about 82%. Consequently it could be concluded that the system of specific strength had a statistically significant influence on the most difficult route climbed this season.

Analysing single regression coefficients it could be concluded that two variables had a statistically significant correlation with the criterion maximal right-hand reach (MRRH = 0.0395) and block under 90° (BL90 = 0.023). This corroborated the fact that maximal right-hand reach and block under 90° heavily influenced the most difficult route climbed this season. Other coefficients were not statistically significant.

TABLE 6: **REGRESSION ANALYSIS OF VARIABLE MDDS BY MEANS OF THE SYSTEM OF VARIABLE SPECIFIC STRENGTH**

Variables	R	Part-R	Beta	Std.Err. of Beta	t(13)	p-level
MRLH	0.737	-0.353	-1.682	0.949	-1.772	0.090
MRRH	0.744	0.423	2.024	0.925	2.189	**0.039**
MRBH	0.746	-0.086	-0.168	0.414	-0.406	0.689
PU2F	0.829	-0.023	-0.034	0.314	-0.110	0.914
HPLH	0.659	-0.065	-0.184	0.600	-0.307	0.762
HPRH	0.662	0.190	0.545	0.600	0.908	0.374
BL90	0.834	0.462	1.140	0.466	2.446	**0.023**
B90L	0.781	-0.010	-0.050	1.044	-0.048	0.962
B90R	0.786	-0.103	-0.557	1.146	-0.486	0.632
R = 0.908	**R^2 = 0.825**	**F(9,22) = 11.538**	**p < 0.000**			

Correlation of the whole system of specific strength and competition standing (COST), i.e. coefficient of multiple correlation, was 0.96 ($R = 0.962$), which explains common variability between the system and criterion variable with about 92% ($R^2 = 0.925$). The remaining 8% in the explanation of the total variability of competition standing can be ascribed to other characteristics and abilities of subjects, which were not considered in this research (other motor abilities, morphological characteristics, etc.) and the conditions during testing. These results provide a statistically significant explanation of the criterion variable by means of specific strength ($p < 0.000$). Thus, it could be concluded that the system of specific strength had a statistically significant influence on competition standing (Table 7).

By analysing single regression coefficients it was observed that a statistically significant correlation with the criterion had only two variables for the estimation of specific static strength: block under 90° (BL90 = 0.015); and block under 90° on left hand (B90L = 0.049). Also, it is clear that the variable block less than 90° on right hand (B90R), was just below the level of significance. This led to the conclusion that block under 90° and block under 90° on left hand had a statistically significant influence on competition standing. Other coefficients were not statistically significantly correlated with the criterion variable COST (Table 7).

TABLE 7: **REGRESSION ANALYSIS OF VARIABLE COST BY MEANS OF THE SYSTEM OF VARIABLE OF SPECIFIC STRENGTH**

Variables	R	Part-R	Beta	Std.Err. of Beta	t(13)	p-level
MRLH	0.814	-0.144	-0.422	0.620	-0.681	0.503
MRRH	0.803	0.179	0.515	0.604	0.852	0.403
MRBH	0.798	0.054	0.068	0.270	0.252	0.803
PU2F	0.777	-0.009	-0.008	0.205	-0.040	0.968
HPLH	0.509	-0.049	-0.090	0.392	-0.230	0.820
HPRH	0.502	-0.012	-0.022	0.392	-0.055	0.956
BL90	0.938	0.490	0.803	0.305	2.637	**0.015**
B90L	0.898	-0.406	-1.420	0.682	-2.083	**0.049**
B90R	0.917	0.395	1.512	0.749	2.019	0.056
R = 0.962	**R^2 = 0.925**	**F(9,22) = 30.325**	**p < 0.000**			

CONCLUSION

Based on the obtained results the following conclusions were drawn:

Success in sport climbing depends on specific strength, mostly on specific static/isometric strength. All variables had statistically significant projections on canonic factor, in particular variables of specific static strength - block under 90˚ angle (BL90), block under 90˚ angle on left hand (B90L) and block under 90˚ angle on right hand (B90R) and variable of the situational-motor explosive strength – maximal reach with left hand (MRLH), maximal reach with right hand (MRRH), maximal reach with both hands (MRBH) and pull-ups with two fingers (PU2F). Since all measures of specific strength were in direct proportion with measures of success in sport climbing it could be concluded that the subjects with greater specific strength will be more successful in sport climbing.

Analysing single criterion variables it could be concluded that specific strength significantly influences the success in all three criteria – the most difficult route climbed up to now (MDCR), the most difficult route climbed this season (MDDS) and competition standings (COST). However, none of the variables individually significantly influenced the most difficult climbed route up to now (MDCR), two variables – maximal reach with right hand (MRRH) and block under 90˚ angle (BL90) – influenced the most difficult route climbed this season (MDDS). Two variables for the estimation of static strength – block under 90˚ angle (BL90) and block under 90˚ angle on left hand (B90L) – influenced competition standings (COST). Bearing in mind that the criteria, the most difficult route climbed this season (MDDS) and competition standings (COST), were responsible for the estimation of the current sport climbing fitness, it could be concluded that the tests for maximal reach with right hand (MRRH), block under 90˚ angle (BL90) and block under 90˚ angle on left hand (B90L) were the best predictors of success in sport climbing. These results could be utilised for the selection and direction of young talents towards sport climbing.

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