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Biometric Model and Classification Functions in Sport Climbing

by

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Scientists have finally taken a greater interest in sport climbing and are trying to define the specific nature and structure of this sport discipline. Previously, studies concentrated on individual factors which affect sport climbing performance. In connection with the diversity and complex structure of this activity, there is a deficiency of studies attempting to describe a given phenomenon in a multidimensional way, which would form the grounds for further training optimization activities. The main research problem of this study was to present a biometric model, describing the best result in "On Sight" (OS) style men's climbing, represented by Contestant Development Index (CDI). Studies were carried out on a group of thirty Polish sport climbing contestants of advanced level, who had an average sport level of VI.4/4+ in OS style. The analysis included 44 variables obtained by means of tests assessing the level of conditioning, coordination, somatic and psychological properties of the examined subjects. This helped in the successful (R2=0.93) explanation of climbing performance with the help of 9 features which best describe this phenomenon. Technique, VO2AT, Fmax., OSB-P, Contr., RR strength, Ape index, Com. r.r, Flex. Analysed during the study was the structure of Contestant Development Performance, also through discriminate analysis and 3 classification functions calculated with its help. Their role here consisted in the detailed selection of contestants for groups of different climbing advancement. Ten variables: Technique, VO2AT, Fmax. , Contr., RR strength, Ape index, Com. r.r allowed to make a very good qualification of the subjects to particular groups, with special distinction of the first group (first advancement level) from the rest.

Key words: *sport climbing, biometric model, classification functions*

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Introduction

Sport climbing is still a developing discipline, requiring much work from the contestants, instructors, future coaches and scholars with the purpose of improving the sports level, breaking barriers of climbing difficulties and achieving the impossible. During recent years there has been an increased number of studies concerning this sport, with attempts to establish physical (Watts, 2004) and psychological (Horning, 2005) aspects of this discipline. Nevertheless, there is still a great lack of knowledge on training, selection and structure of sport climbing. In connection with the diversity and complex structure of this activity, there is a lack of studies attempting to describe this phenomenon in a multidimensional way, thus giving grounds for training optimization activities.

The only existing study based on complex analysis of physiological and anthropometric aspects of climbing is the study by Mermier and colleagues (2000). In result of using the principal component analysis (PCA), three components have been singled out. They have been referred to as the "training component" (grip strength, arm and leg strength, anaerobic power of the upper and lower body, arm endurance, % body fat, self rating), "anthropometric component" (body mass and height, length of lower limbs, arm span,

ape index) and "flexibility component" (range of motion of the hip joint). The authors proved that success in climbing rather depends on the interaction of many factors and not on single features, as it was suggested earlier. Multiple regression of component connections with the score totals acquired in two climbing tests showed that they explain 58.9% (training component), 0.3% (anthropometric component) and 1.8% (flexibility component) of the total performance variation in these two tests. Additionally, the authors themselves suggested more complex tests that would also take into consideration psychological, coordination factors as well as technical and tactical efficiency in order to explain the remaining 34% of the total climbing performance variation.

The surrounding reality is by nature complex and multidimensional and situations where one variable explains a given phenomenon is rather rare. Dependencies of single variables for explaining sport performance can be based on indirect or apparent relationships which obscure the studied phenomenon (Hellwig, 1969; Frankfort-Nachmias C., Nachmias D., 1996; Ryguła, 2003). This is why one should look for methodological solutions (mathematical and statistical instruments) which will help in explaining the complex phenomenon of contestant development conditions, based upon complex testing of sport climbing contestants. The undertaken effort to identify the determinants of Contestant Development Performance, with the use of multidimensional statistical tools (i.e. regression and discriminate analysis) seems fully justified and well-worth developing both critically and creatively.

Queries and Study Hypotheses

1. Which of the somatic features, elements of conditioning and coordination abilities as well as psychological and intellectual properties in the tested climbers have the highest diagnostic value?
2. Which of the analysed qualities best discriminate the tested contestants?
3. To what degree do the variables forming optimum determinant combinations of the biometric model, explain the variation of the studied phenomenon?

The H1 hypothesis assumes that explanatory determinants taken into consideration in the biometric model explain more than three-fourths (¾) of the total variation of the studied phenomenon.

Materials, Methods and Study Tools

A group of 30 sport climbing contestants of advanced sports level (average performance in OS style: VI.4/4+ (VI.3-VI.5+)) comprised the material of these studies. The contestants had a complete set of measurements of all analysed characteristics. The climbing advancement above VI.3 OS formed the selection criteria for the study.

Diagnostic and empirical types of studies were used. During the data collection process, direct observation methods, diagnostic survey and one of the heuristic methods – the Delphian method - were used. Activities in the range of physiological, physical and psychological tests were applied as study techniques. Tests were carried out in standard conditions and were unique for sport climbing, contestant advancement and age of the studied athletes.

In order to carry out statistical analysis of the studied sport climbing group, basic statistical measures, such as: Arithmetic Average (x), Standard Deviation (S), Variation Index (V), Asymmetry Index (As), Kurtosis Index (KU-3) and Pearson-Spearman Correlation (r) were calculated. During the course of further mathematical and statistical analyses, multiple regression and multidimensional data mining technique – discriminate analysis (Ryguła, 2000) was used. For determining climbing performance in the quotient scale, the Contestant Development Index calculated on the ground of Hellwig's algorithm (1968) was used.

Studied Variables

In this study the Contestant Development Index (CDI), based on Wroclaw taxonomy measures (Ryguła, 2000), was the explained variable. It represented the best climbing performance ″without expertise″, accomplished by a contestant (Max OS). In order to compare different climbing scales and to use them in a mathematical analysis, the decimal scale (Köstermeyer, 2000) and conversion table were used.

The role of independent variables is played by results of 44 specified somatic characteristics, specific physical fitness, coordination abilities, body efficiency, technical and tactical abilities, as well as psychological features (tab. 1)

The description of measuring and analytical instruments has been omitted. Their detailed description can be found in the study of Magiera. Determinants of contestant development performance in sport climbing. AWF Katowice 2006.

Study Results

Biometric Model

The biometric model is a formal construction, which by means of one equation or a system of equations, presents basic relations among the studied biological and social phenomena, which include sport training (Ryguła, 2000). In this model, the explained variable (Y) is called an endogenic variable, whereas its explanatory variables (X) are endogenous variables. The most frequent method of creating a model is a multiple regression which has the following single equation formula:

$$Y = f(X1, X2, \ldots, Xk) + \xi$$

Where:
Xi – explanatory variables
ξ – random component

The ideal of sport performance measurement is to express it in physical quantities (metres, seconds, watts). Unfortunately, in classical climbing the difficulty of the climbing path is subjectively determined by its author, which combined with the style of climbing on sight (OS), red point (RP) or flash (FL), determines performance in rock sport climbing. For research purposes this result contains many imperfections. Thus, in order to define the endogenic variable, determined in the strong quotient scale, a synthetic criterion was used – Contestant Development Index (CDI). This index represents the best climbing

Table 1

Descriptive statistics (60n)

(xj)	VARIABLES		x	S	V	As	Ku
Y1	Contestant Development Index (CDI)	n	0,22	0,11	49,57	-0,15	-1,02
Y2	Best performance in OS style	n	8,68	0,53	6,08	-0,05	-1,39
1.	Age of studied contestant	years	26,63	5,45	20,45	0,26	-0,68
2.	Body Mass of studied contestant	kg	68,85	5,02	7,30	-0,73	1,22
3.	Height of studied body	cm	177,90	5,59	3,14	0,04	-0,94
4.	Arm span	cm	180,09	7,02	3,90	-0,10	-1,15
5.	Ape index: RR span/height	cm/cm	1,01	0,02	2,33	0,63	0,38
6.	Quantity of fat tissue	%	10,42	3,28	31,47	0,27	-0,50
7.	Quantity of muscle tissue	%	63,77	8,30	13,01	0,31	0,40
8.	Body Mass Index	kg/m^2	21,82	1,70	7,78	-0,03	-0,30
9.	Body Cell Mass Index	kg/m^2	11,35	2,03	17,86	0,19	-0,24
10.	Range of motion - flexing of leg in hip joint	degrees	118,67	9,95	8,38	0,09	-1,42
11.	Range of motion - leg abduction in hip joint	degrees	51,30	6,95	13,55	-0,19	0,29
12.	Flexibility of hips in "froggies"	cm	6,11	5,10	83,41	0,23	-0,24
13.	Complex reaction rate – number of errors	n	5,87	2,79	47,54	-0,11	-0,78
14.	Stereometry	mm	14,33	10,09	70,36	1,05	0,08
15.	State of balance – instability	deg./s	260,98	54,45	20,86	-1,64	2,95
16.	State of balance – controllability	n	81,80	8,80	10,76	0,13	-0,84
17.	Motor adaptation – error	S*T	168,13	55,77	33,17	0,83	-0,14
18.	Motor adaptation – adaptation rate	s	0,84	0,25	30,09	1,53	2,74
19.	Differentiation	%	87,50	11,53	13,18	-1,08	0,93
20.	Maximum finger strength	kg/kg	0,55	0,06	11,39	-0,33	-0,37
21.	Finger endurance 1010s 70%Fmax	s	358,80	198,67	55,37	1,57	2,02
22.	Arm strength	kg/kg	1,64	0,12	7,44	0,16	-0,63
23.	Arm endurance	s	67,43	13,68	20,28	0,03	-0,97
24.	Total work of upper part of the body	J/kg	157,37	11,50	7,31	-0,93	1,16
25.	Maximum power of upper part of the body	W/kg	6,43	0,38	5,92	-0,46	0,41
26.	Fatigue index	%	17,90	3,10	17,29	-0,11	-0,56
27.	Pmax achievement time	s	7,46	0,91	12,24	0,94	0,83
28.	Pmax maintenance time	s	4,48	0,92	20,47	-0,15	-0,50
29.	Max. oxygen efficiency – arm work	ml/kg/min	36,32	6,64	18,29	-0,32	-0,16
30.	Oxygen consumption on anaerobic threshold	ml/kg/min	24,37	5,52	22,66	-0,26	-0,69
31.	Spatial intelligence	n	36,17	9,48	26,22	-1,18	0,50
32.	Locus of control	n	10,53	4,32	40,97	0,35	0,16
33.	Neurotic character – crude values	n	6,13	3,90	63,64	0,45	-0,43
34.	Extroversion - crude values	n	14,60	5,03	34,47	-0,46	-0,44
35.	Psychotism – raw values	n	10,70	4,18	39,09	-0,28	-0,15
36.	Lie – raw values	n	8,87	3,31	37,35	0,65	0,40
37.	Jauntiness – raw values	n	16,43	2,76	16,82	-0,50	-0,44
38.	Emotional perseverance – raw values	n	10,33	4,40	42,56	-0,09	-0,46
39.	Sensory sensitivity – raw values	n	13,27	4,39	33,07	-0,61	-0,06
40.	Emotional reactivity – raw values	n	6,93	4,37	63,06	0,20	-1,01
41.	Mental strength – raw values	n	12,57	4,99	39,68	-0,83	-0,39
42.	Activity – raw values	n	11,83	3,85	32,49	-0,21	-0,95
43.	Climbing path passage tactics	%	88,37	7,47	8,45	-0,31	-0,54
44.	Climbing path passage technique	n	51,07	3,01	5,90	0,22	-0,12

performance in OS style (max OS) obtained by a contestant. The r-Spearman Correlation shows a high dependency between these two variables (CDI and Max OS) which amounts to r = 0.89. This index was just as effectively used in studies of many sport disciplines where formal and methodological difficulties occurred during assessment of sport performance (Grabiński, Ryguła, Sokołowski, 1977; Pietraszewski, 2004; Ryguła, 1995; 2000; 2003).

Table 2 presents structural parameters of the regression model for Contestant Development Index. Used in this model were variables which were most correlated with the dependent variable and minimally correlated between each other. The value of Beta coefficients allows to compare the relative contributions that each of the independent variables makes in the prediction of the dependent variable.

As the foregoing sheet shows, the most important CDI predictors are the following variables: Technique, VO2AT, Fmax , Contr., OSB-P, End.RR, Ape index, Comp. r.r.,, which are statistically important ($p<0.05$) and Flex. which is statistically insignificant ($p=0,21$). The parameter value of stochastic structure of regression equation r, r2 and corrected r2, reflects the total power of influence of explanatory variables on Y. In turn, r2 indicates that almost 93% of phenomenon variation was explained by variables taken into consideration by the regression model. However, in practice one often uses the corrected R2 which indicates how well-suited would this regression equation be in another test of the same studied population of climbers (Stanisz, 2000). Corrected R2 explains 91% of CDI /WRZ. Therefore, the variables taken into consideration in the studies are good predictors of the sport level.

Table 2

Summing of regression for dependent variables: CDI /WRZ

	BETA	Błąd st.	B	Błąd st.	t(50)	poziom p
Free exp.			-0,411	0,235	-1,750	0,0863
Technique	**0,358**	**0,053**	**0,013**	**0,002**	**6,757**	**0,0000**
VO_2AT	**0,321**	**0,047**	**0,007**	**0,001**	**6,793**	**0,0000**
Fmax	**0,309**	**0,045**	**0,547**	**0,080**	**6,804**	**0,0000**
Contr	**0,254**	**0,044**	**0,007**	**0,001**	**5,749**	**0,0000**
Psych.	**0,221**	**0,042**	**0,006**	**0,001**	**5,214**	**0,0000**
Endr.RR	**0,184**	**0,045**	**0,002**	**0,000**	**4,122**	**0,0001**
Ape index	**-0,164**	**0,044**	**-0,778**	**0,210**	**-3,706**	**0,0005**
Comp.r.r.	**-0,149**	**0,044**	**-0,006**	**0,002**	**-3,374**	**0,0014**
Flex.	0,063	0,049	0,001	0,001	1,270	0,2099

The calculated regression model was subjected to verification, both statistically and in essence. The F global test result, which in the analysis of multiple regression is an absolutely irreplaceable instrument for testing the significance of all parameters, is shown in tab. 3. Critical value F^{α} (9.50) = 2.07. The empirical value of 69.23 is statistically significant (p<0.05). That is why the H0 hypothesis (b1 = 0) should be rejected, since X variables have considerable influence on the dependent variable Y.

Table 3

Variation analysis results of CDI regression coefficients

	Sum	df	Average	F	P level
Regres.	**0,681**	**9**	**0,076**	**69,230**	**0,0000**
Residuals	0,055	50	0,001		
Total	0,735				

By analysing residuals, it is possible to detect any deviations from a normal distribution and verify the biometric model (Stanisz, 2000). One of the main assumptions says that model residuals have normal distribution and that they are homoscedastic (random component variation stability). Figure 1 confirms that the calculated model fulfils the assumption of normal residual distribution, all points run along a straight line. In the neighbouring figure (Fig. 2), one can see a cloud of points without any distinct tendency in residual variation growth with increases in predicted residual value. One can say that the homoscedasticity assumption has been fulfilled.

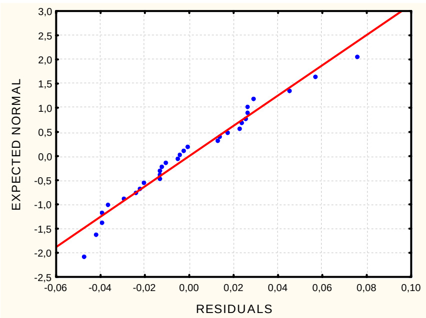

Fig. 1

Normal Probability fo CDI model residuals

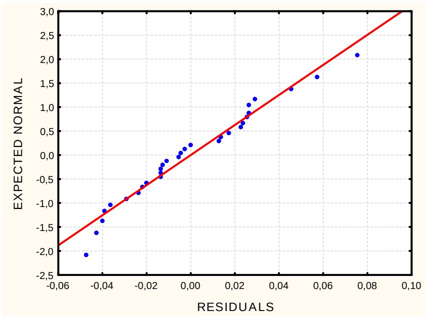

Fig. 2

Chart of predicted values in relation to residuals for CDI model

Versatile verification of the calculated biometric model confirms that this is a good representation of the given phenomenon – Contestant Development Performance in advanced sport climbing.

Classification Functions

These studies comprised a group of sport climbers of advanced level. However, both elite athletes as well as those with a lower sports level were studied. That is why apart from predicting concrete value of the explained variable, the possibility of assigning objects to one of the distinguished classes is also interesting. We treated them as models (sub-systems) that allow for distinguishing differences in Advanced Contestant Development performance. For this purpose, a discrimination analysis was used. This procedure leads to obtaining classification functions which can identify new objects not belonging to the learning set.

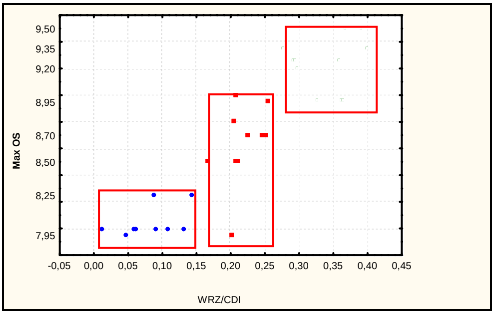

Fig. 3

CDI distribution in relation to Max OS

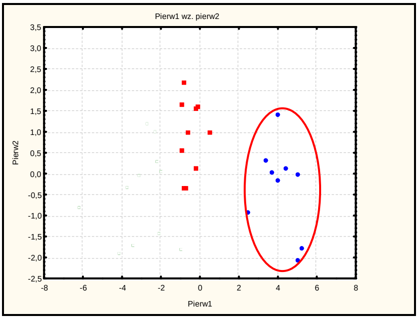

Fig. 4

Chart of distribution discriminant functions

The tested contestants were divided into three groups, similar in number, according to the Contestant Development Index (CDI-cat), representing a different advancement level:

- medium (n=18, CDI: 0.01-0.14),
- high (n=20, CDI: 0.17-0.25),
- master (n=22, CDI: 0.28- 0.40).

Helpful in making the decision on the suitable division into groups was the chart of CDI distribution in relation to Max OS (Fig. 3). Upon applying the step-by-step procedure for selecting variables, 10 features best discriminating the groups were chosen.

Power of the discriminate model is described by Wilks' Lambda. Its value is contained in the range from 1.0 (lack of discriminate power) to 0.0 (excellent discriminate power). In the foregoing model the value of Wilks' Lambda is 0.072, which indicates very good discrimination of objects. A specific contribution of variables in a model is defined by "partial Wilks' Lambda". Such qualities as locus of control, ape index and fat tissue percentage have the biggest share in general discrimination, whereas variables such as psychological resistance and finger strength contribute the least.

Upon analysing the influence of 10 variables on discrimination of the groups, one should return to the main objective of the analysis (i.e., assigning the contestants to specific groups). Three classification functions have been determined, with the following equations:

$$S_1 = \text{-}2560{,}65 + 3{,}86 \times x_{46} - 3{,}53 \times x_{25} + 4575{,}18 \times x_5 + 15{,}17 \times x_1 + 15{,}93 \times x_6 + \\ - 7{,}82 \times x_{32} - 0{,}7 \times x_{18} - 2{,}04 \times x_{32} + 91{,}74 \times x_{21} + 1{,}51 \times x_{43}$$

$$S_2 = \text{-}2382{,}35 + 4{,}8636 \times x_{46} - 3{,}24 \times x_{25} + 4317{,}93 \times x_5 + 14{,}37 \times x_1 + 14{,}05 \times x_6 + \\ - 5{,}92 \times x_{32} - 0{,}62 \times x_{18} - 1{,}34 \times x_{32} + 130{,}55 \times x_{21} + 1{,}51 \times x_{43}$$

$$S_3 = \text{-}2378{,}76 + 5{,}66 \times x_{46} - 3{,}12 \times x_{25} + 4234{,}95 \times x_5 + 14{,}25 \times x_1 + 13{,}24 \times x_6 + \\ - 5{,}21 \times x_{32} - 0{,}6 \times x_{18} - 0{,}95 \times x_{32} + 150{,}34 \times x_{21} + 1{,}17 \times x_{43}$$

General qualification correctness is very high as its amounts to 100%. This is just an ideal model. Our results (although usually not so good) are not surprising, because the cases which served as the basis for calculating discriminate functions were classified. When attributing new cases one should expect decreased qualification correctness.

The use of discriminate function analysis allows for better diagnosing of particular subjects and assessment of Contestant Development Performance. Classification functions are calculated for each group and they can be applied directly to the classification of cases.

Summing up

The main problem of the study was to present a biometric model comprising test results that would best describe a given phenomenon – the best performance in OS style climbing of men in advanced level, represented in this study by the Contestant Development Index (CDI). The results of this study are difficult to compare with the results of other studies, due to the lack of similar analyses. Only Mermier and partners (2000) tried to capture the influence of different characteristics on sport climbing performance. The results of their analysis barely explained 66% of the total variations in Climbers' Development Performance. These studies managed to explain climbing performance almost entirely (R2=0.93), leaving only 7% variation unexplained. As a result of the applied analysis, 9 characteristics, which best describe this phenomenon, were selected from amongst 44 variables: Technique, VO2AT, Fmax, Contr, Psych, End. RR, Ape index, Comp.r.r, Flex.. This model shows that Contestant Development Performance in sport climbing cannot only be defined by means of one variable, but it is a set of different groups of human abilities, skills and properties. This has been confirmed by many authors (Albesa, Lloveras, 2001; Glèe, Rousselet, 2003; Goddard, Neuman, 2000; Guyon, Broussouloux, 2004; Hörst, 2003). The calculated biometric model allows to acknowledge the H1 hypothesis as true because the explanatory variables used in it, explain more than three-fourths (¾) of the total variability of the studied phenomenon.

Analysed in the studies was the structure of Contestant Development Performance, also by means of discriminate analysis. Its role here consisted of the expanded selection of contestants to the advanced climbing groups. Ten variables allowed for very good qualification of studied persons to particular groups (classification correctness amounted to 100%), with particular distinction of the first group (average advancement level) from the rest. Among them was the majority of variables from multiple regression equation of CDI (Technique, VO_2AT, Fmax, Contr, End. RR , Ape index), which confirms their significant role in explaining performance and additional variables (age, FM%, Mot. Ad., Ment. Str.), which were indispensable for suitable grouping of the contestants. The classification functions calculated allowed for better diagnosing of the tested contestants, but when applying them to other new cases one can expect slight deterioration in the effectiveness of their classification.

It is difficult to conclude on climbing level by means of single tests assessing coordination, fitness abilities, body build or mentality of the contestants. Best results can be obtained by defining predictive values of particular trials and tests in different areas of science and then finding an optimum set of variables with the biggest diagnostic and prognostic value. Only on these grounds one can try to predict progress in contestants' development. This study can form the grounds for further research (e.g., on control and optimization), which will serve as an auxiliary tool for non-intuitive control of the training process in sport climbing.

Conclusions

Results of versatile statistical analysis allow to formulate the following conclusions:

1. Based on the value of structural parameters of the regression model, built for the Contestant Development Index in OS style sport climbing, the

following variables have the highest diagnostic value: Technique, VO2AT, Fmax, Contr, Psych., Endr.RR, Ape index, Comp.r.r.,Flex.

2. Features such as: Fmax, Ment.str., End. RR, Age, Technique, VO2AT, Motr.ad., FM%, Ape Index, Contr., best discriminate the tested contestants in sport climbing. The three classification functions designating the groups and studied contestants in a most effective way.
3. Variables which are an optimum combination of determinants of the CDI biometric model, explained 93% of this phenomenon. This shows that the determinants are good predictors of Contestant Development Performance in sport climbing.

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