EVALUATION OF POTENTIAL COMPETITION PERFORMANCE OF YOUNG CROSS-COUNTRY SKIERS BASED ON HIERARCHICAL REGRESSION ANALYSIS AND EXPERT MODELLING

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Abstract:

On a sample of 44 Slovenian cross-country skiers, aged 13-14 years, an attempt of evaluation of competition performance by means of rank-order (hierarchical) regression analysis and expert modelling has been made. Both methodological procedures have the same basis, that is a reduced prognostic performance model, in which motor, morphological and functional dimensions of the psychosomatic status of competitors are arranged hierarchically.

By means of rank-order (hierarchical) regression analysis, 46% of the competition performance of the subjects has been explained. By the procedure of expert modelling, the prognostic competition performance of subjects has been assessed at all levels of the reduced prognostic performance model. A high degree of agreement between the results obtained by the two procedures of evaluation of competition performance (r = 0.86) has been established. The validity of the expert modelling procedure has been determined by linear correlation between the dimensions of prognostic performance and the actual competition performance defined by FIS points (r = 0.55).

In addition to the established model characteristics of young cross-country skiers in this age category, the study has, among other things, also confirmed the assumption about the high value of expert modelling in practical professional direction of the process of training athletes.

Key words: cross-country skiing, young competitors, competition performance, rank-order (hierarchical) regression analysis, expert system, expert modelling

EINSCHÄTZUNG MÖGLICHER WETTBEWERBLEISTUNG VON JUNGEN SKILÄUFERN AUF GRUND DER HIERARCHISCHEN REGRESSIONSANALYSE UND DER MODELLEXPERTISE

Zusammenfassung:

An einer Stichprobe von 44 slowenischen Skiläufern im Alter von 13 bis 14 Jahre wurde die Wettbewerbleistung mit Hilfe von rangeinordnenden (hierarchischen) Regressionsanalyse und Modellexpertise eingeschätzt. Die beiden methodologischen Vorgänge hatten gleichen Ausgangspunkt: das eingeschränkte Modell von Leistungseinschätzung, bei dem die motorischen, morphologischen und funktionellen Dimensionen des psychosomatischen Standes eines Wettbewerbers hierarchisch geordnet sind. Mit Hilfe von rangeinordnenden (hierarchischen) Regressionsanalyse wurde 46% von Wettbewerbleistung der Testpersonen erklärt. Über Vorgang der Modellexpertise wurde von Autoren die vorhergesagte Wettbewerbleistung der Testpersonen auf allen Ebenen der eingeschränkten Modelleistungsvorhersage richtig eingeschätzt. Es wurde ein hohes Grad an Übereinstimmung in den Ergebnissen beider Vorgänge festgestellt (r=0,86). Die Gültigkeit des Vorgangs bei der Modellexpertise wurde über lineare Korrelation zwischen der vorhergesagten und der tatsächlichen Wettbewerbleistung bestätigt, definiert durch Anzahl von FIS-Zahlen (r=0,55). Neben der Feststellung von Modelleigenschaften der jungen Skiläufer im betreffenden Alter wurde in der Arbeit auch die vorausgesetzt hohe Wertstellung der Modellexpertise in praktischer Lenkung bei dem Sporttraining bestätigt.

Schlüsselwörter: Skilauf, junge Wettbewerber, Wettbewerbleistung, rangeinordnende (hierarchische) Regressionsanalyse, Expertsystem, Modellexpertise

Introduction

From the aspect of performance of the athlete we distinguish between the competition and potential prognostic model (Jošt, 1991). The competition performance model enables above all to get to know the already achieved competition performance, while the potential prognostic model tries to predict the performance of the athlete. In the competition model we start from the achieved result (from the consequence to causes), while in the potential prognostic model the situation is reversed (from causes to the consequence, i.e. the expected result).

The basic aim of the research work has been to evaluate the competition performance of the subjects on the basis of two methodological procedures and to determine the validity of the obtained results. However, the procedure of expert modelling adopted - which is based on the findings of some studies carried out by the application of conventional regression procedures (Jošt, 1989; Telama, 1989; Ušaj, 1989) - represents a completely new approach to this complex of problems. The objective of this procedure has been to improve the prognosis of the performance of competitors relative to the absolute age category, irrespective of the instantaneous criterion variable.

The competition performance of the subjects has been assessed on the basis of knowledge about their selected motor, functional and morphological dimensions. All these dimensions (Jošt, 1991) are arranged systematically and hierarchically in the reduced prognostic performance model (see Tables 2, 3, 4, 5) in the form of a linear ramification of the performance decision tree. The structure of the performance model has been based on the results of the research work carried out so far (Kurelić et al., 1975; Stojanović et al, 1995).

Methodology

The sample of test subjects comprised 44 young cross-country skiers from 13 to 14 years of age. The subjects were ranked in the final table of FIS points for the 1992/93 season and measured with all morphological, motor and functional tests.

All data were obtained by single measurements of morphological, motor and functional parameters, carried out in April, 1993. On the basis of the data obtained, the competition performance of the subjects has been assessed according to the following methods:

1. Method of Rank-Order (Hierarchical) Regression Analysis

As a criterion variable of the competition performance of the subjects, FIS points in the 1992/93 season have been used in this method.

The method of regression analysis ENTER has been used in accordance with the reduced prognostic performance model. First, we have studied the relationship on the lowest phenomenological levels of the performance tree, based on the results of conventional regression parameters. On the basis of knowledge about these relationships we have then defined the variables of the higher order in the performance model as linear combinations of the variables of subsystems of the lower order according to the following formula:

$$Svr = B_1 \times Snr_1 + B_2 \times Snr_2 +, ..., B_n \times Snr_n + Constant$$

Svr - variable of higher order

Snr - variable of lower order

B - weights by which the new predictive variable of the higher order is adjusted according to the principle of maximal connection, i.e. the least squares principle

Constant - the value determined by calculation separately for each individual case

The new variables developed combine the common variance of the information of the lower-order variables and have the highest possible correlation with the criterion variable.

By means of the above described procedure, we have thus calculated gradually the new variables on all the higher levels of the performance decision tree up to the highest level "PPERFORM".

The interpretation of the regression analysis in Tables 2, 3, 4 and 5 is based on the following parameters:

Mult R - magnitude of multiple correlation

Rsq - variance of the system

Sig f - validity of the battery of measurement instruments

r - Pearson's coefficient of correlation

rsq - coefficient of determination

P - two-way testing of the significance of the correlation coefficient

B - coefficients of partial regression

Beta - standardised coefficients of partial regression

T - measure of statistical significance

Sig t - characteristic of the T-value

2. Method of Expert Modelling

The results of the measurements have been processed by means of the application of the expert system called the "Sport Expert" (Jošt, 1991).

This method consists of two basic components:

a) Knowledge Base

The knowledge base consists of information about the morphological, motor and functional space of the psychosomatic status of younger

Table 1: Representation of the limits of normalizers for the variables in the functional space

Mark	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
anaetresh	324.6	344.9	358.5	369.7	380.0	390.4	401.9	416.3	439.6
VO_2max	473.6	529.1	566.2	596.7	624.9	653.3	684.7	724.0	787.4

cross-country skiers. In addition to the content-related knowledge, the knowledge base contains also decision rules and normalizers by means of which new knowledge and realizations can be synthesized.

The decision rules (Bohanec et al., 1988) are proportions of individual performance dimensions, expressed in percentages, by which the potential prognostic performance is defined at each node of the performance decision tree. The decision rules are given in Tables 6, 7, and 8 (first column). In formulating the decision rules, the experts have pursued a vision of an ideal top-level cross-country skier in the absolute category.

Normalizers (Bohanec et al., 1988) represent the limits within which value judgements are defined. They are numerically expressed limits of the results in individual dimensions and assign concrete performance marks separately to every individual subject (unsatisfactory, satisfactory, good, very good, excellent).

In Table 1 an example is given of the normalizers developed for the variables in the functional space.

b) Shell of the Expert System

The mechanism of decision-making is based on the logic of the hierarchical linear regresson equation in which the final result equals the sum of the weighted summands of the dimensions of the lower order in the performance model.

All calculation operations have been made by computer according to the following formula:

$$Svr = (Snr_1 \times P) + (Snr_2 \times P) + \ldots + (Snr_n \times P)$$

Svr - normalized value of the variables of the higher order

Snr - normalized value of the variables of the lower order

P - weight of the variable of the lower order (decision rule)

By means of the described method we have thus first calculated for each subject the potential prognostic value of the performance scores at the lowest levels (i. e. tests) of the decision tree in the reduced performance model. Then we have proceeded with successive calculation of the values of variables at higher nodes of the decision tree up to the final highest node, i.e. the general prognostic mark or score of the competition performance of the respective subject.

Results and discussion

The predictive value of the results of the reduced performance model studied on the basis of rank-order (hierarchical) regression analysis

The results which reflect the degree of the predictive power of the variables at individual levels of the performance model are given in Tables 2, 3, 4 and 5.

At the highest level of the performance model we have managed to explain 46% of the performance of the cross-country skiers. The variables which manifest motor dimensions in younger cross-country skiers are a primary predictor in forecasting their competition performance.

Motor space

On the basis of the research results established it is possible to sum up the profile of the motor performance of cross-country skiers in younger age categories.

Table 2: Results of hierarchical regression analysis at the highest level of motor, morphological and functional dimensions

	r	rsq	P					
	Milt r	Rsq	Sig f	B	Beta	T	Sig t	Constant
PPERFORM	0.68	0.46	0.00					-17114.78
¦ MOTOR DIMENSIONS	0.66	0.44	0.00	0.78	0.52	10.29	0.00	-7376.81
¦ MORPHOL. DIMENSIONS	0.53	0.29	0.00	0.31	0.17	1.15	0.29	-9996.17
+ FUNCTION. DIMENSIONS	0.36	0.13	0.05	0.26	0.09	0.52	0.47	91985.10

Table 3: Results of hierarchical regression analysis at all levels of motor dimensions in the performance decision tree

	r	rsq	P				
	Mul R	Rsq	Sig f	B	Beta	T	Sig t
MOTOR. DIMENS.	0.66	0.44	0.00	0.78	0.52	10.29	0.00
¦ENCOMPMOV	0.65	0.43	0.00	0.86	0.56	13.91	0.00
¦ ¦INTEXC	0.49	0.24	0.01	0.43	0.21	2.26	0.14
¦ ¦ ¦ELPOW	-0.28	0.08	0.07	-18.40	-0.11	0.36	0.55
¦ ¦ ¦ +tripjst	-0.28	0.08	0.07	-18.40	-0.11	0.36	0.55
¦ ¦ ¦SPEEDP	0.48	0.23	0.01	0.97	0.46	8.10	0.01
¦ ¦ ¦ ¦medbth	-0.46	0.21	0.00	-47.36	-0.42	8.12	0.01
¦ ¦ ¦ +longjumps	-0.27	0.07	0.08	-72.21	-0.13	0.77	0.39
¦ ¦ +EXPOW	0.13	0.02	0.40	-58.91	-0.12	0.43	0.52
¦ ¦ +runhighst	0.13	0.02	0.40	-58.91	-0.12	0.43	0.52
¦ +EXCDURAT	0.63	0.40	0.00	0.82	0.52	13.76	0.00
¦ ¦ENDPOW	0.36	0.13	0.06	0.23	0.08	0.35	0.56
¦ ¦ ¦REPPOW	0.35	0.12	0.16	0.92	0.32	4.35	0.04
¦ ¦ ¦ ¦benthang	-0.23	0.06	0.13	-440.16	-0.14	0.78	0.38
¦ ¦ ¦ ¦trunklift	-0.18	0.03	0.24	-247.36	-0.06	0.13	0.72
¦ ¦ ¦ +jumpovswb	-0.31	0.09	0.04	-652.20	-0.25	2.35	0.13
¦ ¦ +STATPOW	-0.19	0.04	0.22	-48.55	-0.10	0.45	0.51
¦ ¦ +hangelbb	-0.19	0.04	0.22	-48.55	-0.10	0.45	0.51
¦ +RUNEND	0.63	0.39	0.00	0.94	0.59	18.17	0.00
¦ ¦AEEND	0.32	0.10	0.04	33.37	0.15	1.22	0.28
¦ ¦ +Cooptest	0.32	0.10	0.04	33.37	0.15	1.22	0.28
¦ +ANAEND	0.61	0.37	0.00	0.93	0.57	19.36	0.00
¦ +300 m-run	0.61	0.37	0.00	0.93	0.57	19.36	0.00
+INFOCOMPM	0.50	0.25	0.00	0.29	0.14	0.90	0.35
¦REGSYN	0.46	0.21	0.02	0.74	0.34	4.62	0.04
¦ ¦SPEED	0.36	0.13	0.13	0.94	0.34	5.88	0.02
¦ ¦ ¦tapbhand	-0.24	0.06	0.12	-335.08	-0.16	1.10	0.30
¦ ¦ ¦60-m-run	0.31	0.10	0.04	90.82	0.04	0.02	0.88
¦ ¦ +20-m-runfls	0.32	0.10	0.03	147.95	0.24	0.68	0.41
¦ ¦FLEXIBILITY	-0.14	0.02	0.36	-208.06	-0.09	0.36	0.55
¦ ¦ +bendforwb	-0.14	0.02	0.36	-208.06	-0.09	0.36	0.55
¦ +BALANCE	0.30	0.09	0.15	0.83	0.25	2.84	0.10
¦ ¦balbenchf	-0.13	0.02	0.42	-51.52	-0.08	0.30	0.59
¦ +balbenchsag	-0.28	0.08	0.06	-137.92	-0.27	3.24	0.08
+COORDINAT	0.41	0.17	0.06	0.58	0.23	2.24	0.14
¦polygbackw	0.37	0.14	0.01	235.34	0.35	5.82	0.02
¦eightbend	0.20	0.04	0.18	219.61	0.21	1.25	0.27
+sidestep	0.09	0.01	0.57	-113.58	-0.09	0.26	0.61

At the highest level in the motor space which determines the performance of younger cross-county skiers, the mechanism of energy regulation of movement - which accounts for the movement efficiency of cross-country skiers from the aspect of energy component - has the most important role. Within this dominant mechanism, the mechanism for the duration of excitation of the neuro-muscular system is at the centre of attention due to the fact that the movements in cross-country skiing are of a cyclical endurance nature. Within the mechanism for the duration of excitation of the neuro-muscular system, the variables which represent the so-called basic running endurance, and which are also contaminated with functional abilities, have shown to be in our case the best predictive variables. As to the kind of movement execution, they are also closest to the pattern of movements in cross-country skiing.

The action of the mechanism for the regulation of the intensity of excitation of the neuro-muscular system within the mechanism of energy regulation of movement occurs also as an important predictor of the competition performance. Especially the variables of the so-called speed strength of the arms and shoulder girdle (medbth) have contributed the largest share to performance.

The mechanism accountable for the efficient solution to motor problems of an information type, which is defined by the mechanism for control of synergists and antagonists and the mechanism for structuring the movement, has also contributed significantly to the explanation of competition performance. Within the mechanism of the information component of movement, the mechanism for control of synergists and antagonists was more prevalent. In this mechanism, speed defined by the variables of the speed type was the most

Table 4: Results of hierarchical regression analysis at all levels of morphological dimensions in the performance decision tree

	r	rsq	P					
	Mult r	Rsq	Sig f	B	Beta	T	Sig t	Constant
MORPHOL. DIMENSIONS	***0.5***	***0.29***	***0.00***	***0.31***	***0.17***	***1.15***	***0.29***	***-9999.17***
¦DIMSKELET	0.4;	0.18	0.02	0.40	0.17	1.05	0.31	-5451.68
¦ ¦LENGTHSK	0.4'	0.17	0.02	0.72	0.30	1.73	0.20	45489.74
¦ ¦ ¦HEIGHT	-0.4C	0.16	0.01	-18.70	-0.14	0.12	0.73	
¦ ¦ ¦ +bodyh	-0.4C	0.16	0.01	-18.70	-0.14	0.12	0.73	
¦ ¦ +LENGTHBSEG	0.4'	0.17	0.02	0.68	0.28	0.50	0.49	-3982.08
¦ ¦ ¦LENGTHARM	0.3	0.14	0.04	0.37	0.14	0.30	0.59	137107.60
¦ ¦ ¦ ¦lengthlarm	-0.37	0.14	0.01	-165.61	-0.52	2.97	0.09	
¦ ¦ ¦ +lengthlupa	-0.2	0.08	0.06	97.89	0.17	0.31	0.58	
¦ ¦ +LENGTHLEG	0.4(	0.16	0.03	0.71	0.28	1.21	0.28	128005.79
¦ ¦ ¦lengthlleg	-0.4C	0.16	0.01	-91.06	-0.43	4.17	0.05	
¦ ¦ +lengthlth	-0.2	0.08	0.07	14.34	0.04	0.04	0.84	
¦ +WIDTHSKELET	0.3	0.14	0.10	0.39	0.15	0.43	0.52	-26199.47
¦ ¦LEGWIDTH	0.2(	0.04	0.43	0.58	0.12	0.45	0.51	72504.95
¦ ¦ ¦diamleftkn	-0.1	0.03	0.25	-455.41	-0.26	1.63	0.21	
¦ ¦ +diamleftan	-0.0	0.00	0.77	277.44	0.12	0.38	0.54	
¦ ¦TRUNKWIDTH	0.3	0.13	0.06	0.88	0.32	1.88	0.18	107098.25
¦ ¦ ¦shouldwid	-0.3	0.13	0.02	-171.14	-0.36	4.45	0.04	
¦ ¦ +pelvwid	-0.1	0.04	0.22	1.34	0.00	0.00	0.99	
¦ +ARMWIDTH	0.3;	0.10	0.11	0.07	0.02	0.01	0.93	100468.28
¦ ¦dialwrist	-0.31	0.09	0.04	-578.87	-0.22	0.99	0.32	
¦ +dialelbow	-0.2	0.08	0.06	-324.94	-0.12	0.32	0.58	
+VOLUMDIM	0.5;	0.27	0.01	0.80	0.41	6.05	0.02	-15578.35
¦CIRCUMF	0.4	0.23	0.02	0.77	0.37	5.01	0.03	159157.77
¦ ¦CIRCARM	0.3	0.11	0.09	1.49	0.49	4.32	0.04	82939.23
¦ ¦ ¦circluparm	-0.27	0.07	0.07	225.30	0.44	0.57	0.45	
¦ ¦ +maxcluparm	-0.31	0.10	0.04	-339.73	-0.73	1.62	0.21	
¦ ¦TRUNKCIR	0.3	0.11	0.10	1.19	0.39	3.21	0.08	102227.33
¦ ¦ ¦normcchest	-0.2	0.09	0.05	43.58	0.21	0.15	0.70	
¦ ¦ +maxcchest	-0.3	0.10	0.03	-104.82	-0.53	0.94	0.34	
¦ +LEGCIRCUMF	0.1'	0.01	0.76	-4.88	-0.56	5.15	0.03	65607.05
¦ ¦circlthigh	-0.11	0.01	0.46	-34.46	-0.12	0.24	0.63	
¦ +circlshank	-0.0	0.01	0.58	1.03	0.00	0.00	0.99	
¦WEIGHT	-0.3C	0.09	0.05	-18.16	-0.13	0.64	0.43	
¦ +bodyw	-0.3C	0.09	0.05	-18.16	-0.13	0.64	0.43	
+FATTIS	0.2	0.08	0.35	0.71	0.20	1.96	0.17	-31171.39
¦FATTISA	0.1(	0.03	0.29	2.27	0.0	0.00	0.98	
¦ +skflefupa	0.1(	0.03	0.29	2.27	0.00	0.00	0.98	
¦FATTRUNK	0.1	0.02	0.65	00.70	0.10	0.43	0.52	56380.76
¦ ¦skfback	-0.0	0.00	0.74	-207.15	-0.19	0.73	0.40	
¦ +skfstom	0.0(	0.00	0.70	65.79	0.19	0.76	0.39	
+FATTISLEG	0.2(	0.07	0.24	0.92	0.24	1.58	0.22	16285.63
¦skflthigh	0.2(	0.07	0.09	6442.69	0.20	0.94	0.34	
+skflshank	0.2;	0.05	0.16	18.94	0.07	0.12	0.73	

pronounced factor. The mechanism for structuring movements or co-ordination has not explained the competition performance of young cross-county skiers within the limits of statistical significance. Above all, the variable which falls into the area of the kinetic solution of space-related problems has shown in this segment the largest predictive power in forecasting the performance of young cross-country skiers.

Morphological Space

The results of the analysis are given in Table 4.

On the basis of the results of the analysis of the connection between morphological space in young cross-country skiers and their competition performance, the following theoretical morphological profile of young cross-country skiers can be defined:

- emphasized are the circumferences of the body and the related body weight and height

- low amount of subcutaneous fat tissue and

- pronounced transversity in the region of the shoulder girdle and wrists.

Functional Space

The results of the analysis are given in Table 5.

The functional dimensions have explained the criterion variable of the competition performance on the border of statistical significance.

In the formulation of the variables of the higher order within the functional dimensions, only the variable of maximum oxygen consumption (VO_2MAX) has contributed to a statistically significant share. This variable has also explained the statistically significant

Table 5: Results of hierarchical regression analysis at all levels of functional dimensions in the performance decision tree

	r	rsq	P					
	Mult r	Rsq	Sig f	B	Beta	T	Sig t	Constant
FUNCTION. DIM.	***0.36***	***0.13***	***0.05***	***0.26***	***0.09***	***0.52***	***0.47***	***91985.10***
¦ ***anaertresh***	-0.13	0.02	0.39	-9.87	-0.02	0.02	0.88	
+ ***VO_2max***	-0.36	0.13	0.02	-56.48	-0.35	5.29	0.03	

competition performance, which points out that even in this age category of cross-country skiers the ability of maximum oxygen consumption is an important predictor of the competition performance. For the high level competition performance in cross-country skiing (Åstrand, 1986), where loadings of aerobic type occur, the ability of maximum oxygen consumption is one of the fundamental factors of performance.

Results and interpretation of prognostic competition performance established by means of the method of expert modelling

In Tables 6, 7 and 8, the results of potential prognostic performance for four selected young cross-country skiers are given. In Table 6, marks of potential performance at the highest level of the potential prognostic performance model are given in the first line (PPERFORM); these are then followed at lower levels by the marks of the individual subspaces of the previously defined dimensions of the performance model.

From the aspect of the potential prognostic performance, the best mark has been assigned to the competitor under the consecutive number 4 who has received the mark (3.9) which ranks him in the zone of a very good potential prognostic performance. Two competitors have been assigned the marks in the zone of good performance, and one competitor in the zone of a satisfactory potential prognostic performance.

The first competitor has been given the mark 3.4 which ranks him in the zone of good performance close under the level of a very good potential prognostic performance. The mark 'good' has been assigned to the competitor since at the first three lower levels of potential prognostic model of performance he has received an excellent mark (4.4) in the morphological space, in the motor space 3.2 (good) and in the functional space 3.0 (good).

A detailed analysis of the results for competitor No. 1 in the individual subspaces of the performance model is given.

Motor Space

In the basic motor space, subject No. 1 has a slightly more developed information component of movement (INFOCOMPM - this is a composite complex dimension of motor dimensions inside of which there prevails, from the aspect of performance, the ability to receive, formulate and produce information required for the execution of a particular movement); however, both the information component and the energy component of movement (ENCOMPMOV in which the requirement for the capability of generation and consumption of energy necessary to perform a particular movement prevails) have been scored as good. It is obvious that the competitor will have to improve his performance in both components of the basic motor abilities in order to advance in cross-country skiing. This applies specially to the energy component of movement to which a larger share of import is attributed by experts.

Within the scope of the factors of the energy component of movement (ENCOMPMOV), both the intensity and the duration of excitation of the neuro-muscular system have been assigned the value 3.2 (good). Basic running endurance (RUNEND) within the scope of excitation duration has been assessed to be on

Table 6: Marks of the expected competition performance at the highest levels of the performance model

	DR	1	2	3	4
PPERFORM	***100***	***3.4***	***2.8***	***3.3***	***3.9***
¦ ***MOTOR DIM.***	45	3.2	2.0	3.1	3.8
¦ ***MORPHOL. DIM.***	20	4.4	3.2	4.3	4.3
+ ***FUNCTION. DIM.***	35	3.0	3.7	2.9	3.8

Descriptive mark values:
> 1.9 unsatisfactory
2.0 - 2.9 satisfactory
3.0 - 3.4 good
3.5 - 3.9 very good
4.0 < excellent

Legend:
DR - decision rules (expressed in %)
1, 2, 3 and 4 : numerical designation of the tested subjects

Table 7: Results of the expert system in the space of motor dimensions of the young cross-country skiers' performance

	DR	1	2	3	4	
MOTOR DIMENS.	100	3.2	2.0	3.1	3.8	MOTOR DIMENSIONS
¦ENCOMPMOV	70	3.2	1.7	3.0	3.9	ENERGY COMPONENT OF MOVEMENT
¦ ¦INTEXC	30	3.2	2.2	3.7	4.1	EXCITATION INTENSITY
¦ ¦ ¦ELPOW	20	3.7	2.1	4.0	4.3	ELASTIC POWER
¦ ¦ ¦ +tripjst	100	3.7	2.1	4.0	4.3	Triple jump from a standstill
¦ ¦ ¦SPEEDP	40	3.4	2.7	3.7	4.3	SPEED STRENGTH
¦ ¦ ¦ ¦medbth	55	4.2	3.4	3.6	4.4	Medicine ball throw
¦ ¦ ¦ +longjumps	45	2.4	1.8	3.9	4.2	Long jump from a standstill
¦ ¦ +EXPOW	40	2.7	1.9	3.5	3.7	EXPLOSIVE POWER
¦ ¦ +runhighst	100	2.7	1.9	3.5	3.7	20 m run – high start
¦ +EXCDURAT	70	3.2	1.5	2.8	3.8	EXCITATION DURATION
¦ ¦ENDPOW	30	3.5	3.8	3.3	3.5	ENDURANCE POWER
¦ ¦ ¦REPPOW	70	2.0	2.8	3.1	3.5	REPETITIVE POWER
¦ ¦ ¦ ¦benthang	30	2.5	2.5	2.5	3.5	Bent hangs on parallel bars
¦ ¦ ¦ ¦trunklift	30	2.4	3.4	2.7	2.4	Trunk lifting
¦ ¦ ¦ +jumpovswb	40	1.5	2.6	3.8	4.3	Jumps over Swedish bench
¦ ¦ +STATPOW	30	3.5	3.5	3.8	3.4	STATIC STRENGTH
¦ ¦ +hangelbb	100	3.5	3.5	3.8	3.4	Hang with elbows bent
¦ +RUNEND	70	3.4	0.8	2.5	3.9	BASIC RUNNING ENDURANCE
¦ ¦AEEND	65	3.1	0.9	2.2	3.7	LONG ENDURANCE
¦ ¦ +Cooptest	100	3.1	0.9	2.2	3.7	Cooper test (2400 m)
¦ +ANAEND	35	4.1	0.7	3.2	4.5	SPEED ENDURANCE
¦ +300 m-run	100	4.1	0.7	3.2	4.5	300 m run
+INFOCOMPM	30	3.4	2.9	3.2	3.8	INFORMATION COM. OF MOVEMENT
¦REGSYN	55	3.3	3.1	3.4	3.7	REGULATION OF MUSCLE
¦ ¦SPEED	45	2.8	2.3	3.6	4.1	SPEED
¦ ¦ ¦tapbhand	30	2.8	3.0	3.2	3.7	Tapping with a better hand
¦ ¦ ¦60-m-run	40	2.9	1.6	3.6	4.3	60 m run
¦ ¦ +20-m-runfls	30	2.8	2.3	4.0	4.3	20 m run with flying start
¦ ¦FLEXIBILITY	25	3.6	3.8	3.2	3.8	FLEXIBILITY
¦ ¦ +bendforwb	100	3.6	3.8	3.2	3.8	Bending forward on bench
¦ +BALANCE	30	3.6	3.8	3.4	3.1	BALANCE
¦ ¦balbenchf	55	4.1	3.8	4.7	2.9	Balance on bench – frontal
¦ +balbenchsag	45	3.0	3.9	1.8	3.4	Balance on bench – sagittal
+COORDINAT	45	3.6	2.5	3.0	3.8	CO-ORDINATION
¦polygbackw	40	3.9	2.4	1.9	3.8	Polygon backwards
¦eightbend	30	3.8	2.0	3.1	3.2	Eight with bending
+sidestep	30	3.1	3.2	4.3	4.3	Side steps

the border between good and very good (an excellent result prevails in speed endurance - 300-M- RUN), while the subsegment of repetitive power has been relatively poorly scored (REPPOW). In the test of jumps over a Swedish bench (jumpovswb), the subject has achieved the worst result of all with the score 1.5 (unsatisfactory). We can say with certainty that in the further process of training the subject will have to devote great care to the development of repetitive power.

Within the scope of the information component of movement (ENCOMPM), co-ordination (COORD) of the subject has been scored as very good, while the operation of the mechanism for regulation of synergists and antagonists of the neuro-muscular system (REGSYN) has been scored as good. Within the said mechanism, the abilities of balance and speed have been scored as very good. Speed stands out with a low mark (2.8) which has been determined by speed tests TAPBHAND, 60 -M-RUN and 20 -M-RUN on which the scores are similar.

Morphological space

In the morphological space, the test subject has achieved an excellent result (Table 8.). This predicts him, as regards this factor, high competition performance in the absolute age category. The subject has received the mark 'excellent' because he was excellent in all the essential subsystems of the morphological part of the reduced potential prognostic performance model.

Functional space

The total mark of the subject attained in the functional space is 3.0 which means very good. (Table 9). The competitor has achieved a better mark in the VO_2MAX test, i.e. maximal oxygen consumption, which, in the opinion of experts, is one of the most important indicators of competition performance above all in the period of the top-level sports capacity of competitors.

Table 8: Results of the expert system in the morphological space of the young cross-country skiers' performance

	DR	1	2	3	4	
MORPHOL. DIMENS.	***100***	***4.4***	***3.2***	***4.3***	***4.3***	***MORPHOLOGICAL DIMENSIONS***
¦DIMSKELET	40	3.4	2.4	4.3	4.1	SKELETON DIMENSIONS
¦ ¦LENGTHSK	50	4.6	1.9	4.6	4.5	LENGTH DIM. OF SKELETON
¦ ¦ ¦HEIGHT	50	4.8	1.6	4.9	4.7	BODY HEIGHT
¦ ¦ ¦ +bodyh	100	4.8	1.6	4.9	4.7	Body height
¦ ¦ +LENGTHBSEG	50	4.4	2.1	4.3	4.3	LENGTH OF BODY SEGMENTS
¦ ¦ ¦LENGTHARM	45	4.6	2.6	4.4	4.5	LENGTH OF ARMS
¦ ¦ ¦ ¦lengthlarm	55	4.5	2.7	4.4	4.3	Length of left arm
¦ ¦ ¦ +lengthlupa	45	4.6	2.5	4.5	4.7	Length of left upper arm
¦ ¦ +LENGTHLEG	55	4.3	1.7	4.2	4.1	LENGTH OF LEGS
¦ ¦ ¦lengthlleg	60	4.4	1.8	4.5	4.1	Length of left leg
¦ ¦ +lengthlth	40	4.2	1.5	3.8	4.1	Length of left thigh
¦ +WIDTHSKELET	50	4.0	3.0	4.0	3.6	WIDTH DIMENS. OF SKELETON
¦ ¦LEGWIDTH	30	3.7	2.2	3.3	2.9	LEG WIDTH
¦ ¦ ¦diamleftkn	55	4.3	2.5	4.5	3.7	Left knee diameter
¦ ¦ +diamleftan	45	2.9	1.8	1.8	2.0	Diameter of left ankle
¦ ¦TRUNKWIDTH	40	4.1	3.6	4.5	4.3	TRUNK WIDTH
¦ ¦ ¦shouldwid	60	4.1	3.1	4.4	4.4	Shoulder width
¦ ¦ +pelvwid	40	4.2	4.2	4.5	4.0	Pelvis width
¦ +ARMWIDTH	30	4.1	3.1	4.2	3.5	ARM WIDTH
¦ ¦dialwrist	50	3.9	2.9	4.3	3.1	Diameter of left wrist
¦ +dialelbow	50	4.3	3.3	4.2	4.0	Diameter of left elbow
+VOLUMDIM	60	4.4	3.6	4.2	4.4	VOLUMINOSITY DIMENSIONS
¦CIRCUMF	40	4.0	3.3	3.7	4.1	CIRCUMFERENCES
¦ ¦CIRCARM	30	4.0	3.7	3.6	4.4	CIRCUMFERENCE OF ARMS
¦ ¦ ¦circluparm	45	4.0	3.8	3.8	4.3	Circumference of left upper arm
¦ ¦ +maxcluparm	55	4.1	3.6	3.3	4.4	Max. circumference of left upper arm
¦ ¦TRUNKCIR	40	4.0	3.3	3.8	4.3	TRUNK CIRCUMFERENCE
¦ ¦ ¦normcchest	40	3.9	3.3	3.8	4.1	Normal circumference of chest
¦ ¦ +maxcchest	60	4.0	3.4	3.8	4.5	Maximal circumference of chest
¦ +LEGCIRCUMF	30	3.8	2.9	3.6	3.5	LEG CIRCUMFERENCE
¦ ¦circlthigh	45	4.0	3.1	3.5	3.7	Circumference of left thigh
¦ +circlshank	55	3.7	2.8	3.7	3.4	Circumference of left shank
¦WEIGHT	30	4.8	3.2	4.7	4.7	WEIGHT
¦ +bodyw	100	4.8	3.2	4.7	4.7	Body weight
+FATTIS	30	4.5	4.5	4.5	4.5	FAT TISSUE
¦FATTISA	30	4.7	4.2	4.7	4.8	FAT TISSUE OF ARMS
¦ +skflefupa	100	4.7	4.2	4.7	4.8	Skin fold of left upper arm
¦FATTRUNK	35	4.9	4.5	4.5	4.7	FAT TISSUE OF TRUNK
¦ ¦skfbackt	50	4.9	4.6	4.6	4.6	Skin fold of back
¦ +skfstomt	50	4.9	4.3	4.4	4.9	Skin fold of stomach
+FATTISLEG	35	4.1	4.8	4.5	4.1	FAT TISSUE OF LEGS
¦skflthigh	45	3.5	4.9	4.4	4.9	Skin fold of left thigh
+skflshank	55	4.6	4.8	4.6	3.5	Skin fold of left shank

Agreement and validity of the results of the selected procedures of evaluation of competition performance in young cross-country skiers

Agreement between the results of both procedures of evaluation of competition performance has been determined by correlation between the general prognostic performance marks obtained as a result of the application of the method of expert modelling and the results of rank-order (hierarchical) regression analysis comprised in the variable showing the maximum multiple connection with competition performance.

Correlation ($r = -0.86$) shows a high degree of agreement between the results. In this age category, this suggests a comparatively high agreement between the competition performance and the prognostic performance based on the forecasting of performance in the absolute category of top cross-country skiers. A part of the disagreement of the results confirms again the fact that the performance of young cross-country skiers is not defined by the same mechanisms as in the absolute age categories owing to the specific nature of the development stage and competition conditions (shorter competition distances).

The validity of the results of expert modelling

Table 9: Results of the expert system the "Sport expert" in the space of functional dimensions of the young cross-country skiers' performance

	DR	1	2	3	4	
FUNCTION. DIMENS.	***100***	***3.0***	***3.7***	***2.9***	***3.8***	***FUNCTIONAL DIMENSIONS***
¦ ***anaertresh***	40	2.6	3.3	2.5	3.2	Conconi test
+ ***VO_2max***	60	3.3	3.9	3.2	4.2	Treadmill

has been established by correlation between the general prognostic marks of performance and the variable of actual performance of competitors expressed in FIS points (r=0.55). A slightly higher degree of correlation between the predictive and actual performance has been obtained by the procedure of conventional rank-order (hierarchical) regression analysis (r=0.68). However, this finding should be, at least hypothetically, treated with a high degree of caution as the competition performance analysed in this study can also differ considerably from the structure of competition performance in the absolute age category. This assumption is confirmed in every-day practice in which we can establish that good competition results of cross-country skiers in younger age categories are not a reliable guarantee for the high competition performance in the absolute age category.

Conclusions

The results of the assessment of the competition performance of young cross-country skiers (aged 13-14 years) obtained by means of expert modelling and rank-order (hierarchical) regression analysis have contributed important new information to the field of theory and expert practice of cross-country skiing. We have constructed a reduced hierarchical model of prognostic the competition performance and on the basis of this model we have successfully explained 46 % of competition performance in the test subjects by the procedure of rank-order (hierarchical) regression analysis and have established their model characteristics in this development stage. We have established a satisfactory degree of validity of the procedure of expert modelling, which represents a more innovative approach to the methodology of prediction of competition performance. The results of this procedure provide a possibility to improve the quality of selectioning, diagnosing and the modelling of the training process. These results are easy to understand and employ in expert practice, so that on the basis of the knowledge of the structure of performance in competitors, the coaches will be enabled to select more successfully those methods of transformation by which athletes will develop more strongly, above all, those abilities and properties of competitors that are poorly developed. We expect that by a gradual upgrading of the expert system - above all by its expansion to other factors of performance - the predictive strength of expert modelling in forecasting the competition performance of athletes will even increase in the future.

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