FACTOR STRUCTURE OF SELECTED MORPHOLOGICAL, MOTOR AND BIOMECHANICAL VARIABLES IN SKI JUMPERS

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The purpose of the research study was to establish in a sample of elite Slovene ski jumpers (N = 67) a latent structure of referentiality of manifest area of the selected biomechanical, morphological and motor variables. Through factor analysis 6 factors were excluded out of 35 manifest variables in total. In the first factor (55% of total variance) the highest projections were identified in the basic motor and morphological variables. The second factor was defined by the push-off power variables, in which in terms of scale of factor loading the index of take-off explosive power (0.74) and the related push-off time (0.97) were predominant. In the third factor, the projection of morphological aerodynamic index (0.98) was predominant. The projection of the variable velocity power index, which was calculated on the basis of the ratio in the first and second parts of ski jumpers' push-off, was prevalent in the fourth factor. In the fifth factor, the projection of morphological take-off index (0.93) was predominant. The projection of the age variable (0.95) was prevalent in the last – the sixth factor. The results are interesting primarily because they reflect the specificity in expressing of individual factors, as it is conditioned by ski jumps i.e. their specific movement technique.

KEY WORDS: ski jumping, motor behaviour, morphology, take-off explosive power, factor analysis

INTRODUCTION: The purpose of the present research study was to establish a factor structure in a selected sample of morphological variables and selected motor variables as well as identify the parameters of ski jumpers' push-off power in execution of a vertical jump in laboratory conditions. The ski jumping technique involves a complex motor task. The most important part of the jump is the take-off, which in technical terms requires optimal timing of push-off, optimal aerodynamic efficiency and optimal push-off power. The push-off power receives the most research attention in the training process (Virmavirta, M. & Komi, P. V., 1993; Virmavirta, M. & Komi, P. V., 1994; Vaverka F., 1987; Komi, P. V. & Virmavirta M. 1997) In terms of biomechanics, power and/or final velocity of push-off is defined as a ratio between the force impulse and ski jumper's mass and equipment. Explosiveness of ski jumper's push-off is defined as a ratio between the final velocity of the push-off and the time required to attain this velocity. Ski jumper should possess a high level of explosive power. This may only be achieved when they are capable of developing a high starting and acceleration force.

Ski jumper's transition from the approach position to the optimal position for flight is a complex and difficult motor task, which in terms of motor behaviour terminology requires a high level of strength, co-ordination, accuracy, balance, orientation in space, visualisation, boldness, courage etc. Therefore, in the transition phase, the differences between the best and worst ski jumpers are consequently seen (Arndt, Brugemann, Virmavirta, & Komi, 1994; Vaverka, Janura, Elfmark, & Salinger, 1997) in the flight kinematics that is established on the dynamic level (Watanabe K. & Watanabe I., 1993; Hiroshi, Shunsuke, Tadaharu, Hirotoshi, & Kazutoshi, 1995) in an experimental study in a wind tunnel.

METHODS: The research was conducted on a sample of 67 ski jumpers, members of the Slovene cadet, junior-men and senior-men team selections. The sample included almost all elite Slovene ski jumpers. The sample of variables consisted of 14 morphological and 13 motor variables. The characteristics of ski jumpers' push-off in laboratory conditions were examined by means of 8 biomechanical variables of push-off power. Ski jumpers executed a vertical jump from a specific inrun position on a Kistler Force Plate. Based on the achieved and calculated take-off parameters, the following variables were selected for the purpose of this research: push-off height, push-off time, ratio between push-off height and time (also called index of take-off explosive power) and acceleration of the first part of push-off (also

called index of explosive power of the first part of take-off). The morphological aerodynamic index shows the ratio between the ski jumper's body surface area and their body mass. The morphological take-off index shows the ratio between the ski jumper's body height and their leg length. In ski jumping it is hypothetically assumed that the higher the value of indexes, the higher the potential performance. The measurements were carried out on 15 October 2004. The factor analysis was made on the basis of the Principal Component Analysis.

RESULTS: The results of the research are given in Table 1. Based on factor analysis, six factors were ruled out.
In the first dominant factor, accounting for 55% of total variance, the motor behaviour variables and selected morphological variables showed the highest projections. According to the structure of the factor with manifest variables, this is the GENERAL MORPHOLOGICAL-MOTOR FACTOR OF SKI JUMPERS. The variables of the push-off explosive power formed a homogeneous structure of the second factor which may with good reason be called the factor of EXPLOSIVE PUSH-OFF POWER. According to the scale of factor loading, the following variables were predominant in this factor: index of explosive take-off power (–0.74), index of explosive power of the first part of take-off (–0.66) and push-off time in vertical take-off (0.97). In the third, more specific factor i.e. FACTOR OF AERODYNAMIC CAPABILITY, the projection of morphological aerodynamic index (0.98) was prevalent. A high factor saturation was also seen in body mass (–0.70) and body mass index (–0.94). In the fourth factor of ASYMMETRIC PUSH-OFF POWER, accounting for 5.3% of total variance, the variables of asymmetric push-off power prevailed. In the fifth factor MORPHOLOGICAL INDEX OF TAKE-OFF ROTATION the following projections of morphological variables were predominant: morphological take-off index (0.93) and the related variables of the longitudinal dimension of legs. The projection of the variable AGE (0.95) was strongly prevalent in the last – the sixth factor.

Table 1 Structure of factors and factor loading of the selected morphological variables of ski jumpers and parameters of their push-off power, n=67.

			FACTOR SCORE						Cum.
NAME OF FACTORS	M	S.D.	FAC1	FAC2	FAC3	FAC4	FAC5	FAC6	
GENERAL MORPHOLOGICAL-MOTOR FACTOR									
Repetitive leg power – rep.	79.8	24.7	**0.77**	-0.07	-0.13	0.04	-0.09	0.08	0.87
Repetitive power of abdominal muscles – rep.	16.5	3.8	**0.65**	-0.19	-0.08	0.25	0.06	0.13	0.71
Horizontal jump length – cm	224.3	38.4	**0.63**	-0.11	-0.15	0.02	-0.24	0.19	0.96
Elastic power in triple jump – cm	695.7	127.1	**0.62**	-0.13	-0.16	0.03	-0.21	0.21	0.96
Balance in frontal plane s/10	9.58	9.41	**0.52**	0.00	-0.14	-0.17	0.03	0.29	0.63
Balance in sagital plane s/10	6.58	7.00	0.26	0.09	-0.06	-0.03	0.12	**0.71**	0.74
Speed of right leg frequency – rep.	31.4	5.1	**0.83**	-0.07	0.02	-0.12	0.02	0.13	0.86
Speed of left leg frequency – rep.	29.7	5.3	**0.79**	-0.03	0.05	-0.08	0.02	0.23	0.88
Elasticity of hips – cm	56.5	6.1	**1.00**	0.04	-0.05	-0.10	0.22	-0.07	0.88
Co-ordination in jump-overs – s/10	6.3	1.5	**-0.74**	0.09	-0.05	-0.11	0.29	-0.02	0.85
Co-ordination in an "eight" – s/10	17.4	1.9	**-0.78**	0.03	-0.03	-0.07	0.13	-0.11	0.82
Co-ordination of atypical movement – s/10	8.9	2.7	**-0.97**	-0.04	-0.12	0.04	0.03	0.02	0.86
Body height – cm	160.2	15.0	**0.45**	0.12	-0.45	-0.00	-0.33	0.14	0.97
Shoulder width – cm	35.0	3.9	**0.62**	0.01	-0.46	0.01	-0.12	0.03	0.92
Pelvis width – cm	28.2	3.6	**0.62**	0.05	-0.48	0.07	-0.22	0.26	0.85
Vertical push-off height – cm	39.1	10.3	**0.54**	-0.33	-0.01	0.11	-0.19	0.30	0.95
Impulse of the push-off force –Ns	139.9	49.2	**0.43**	-0.12	**-0.49**	0.04	-0.18	0.20	0.98
EXPLOSIVE POWER FACTOR									
Index of take-off explosive power	69.4	11.9	0.36	**-0.74**	-0.04	0.06	-0.11	0.14	0.98
Acceleration in take-off in the first part – m/s^2	5.6	1.0	0.17	**-0.66**	-0.06	**-0.56**	-0.06	0.00	0.91
Acceleration in take-off in the second part – m/s^2	7.0	1.1	0.10	**-0.68**	0.01	**0.55**	-0.12	0.19	0.91
Push-off time in vertical take-off – s/1000	402.4	33.7	0.11	**0.97**	0.06	0.05	-0.10	0.11	0.96
Starting acceleration in push-off (m/s^2)	1.64	0.6	0.08	**-0.54**	-0.05	**-0.49**	0.13	0.15	0.70
MORPHOLOGICAL AERODYNAMIC FACTOR									
Aerodynamic index	1087.5	99.1	0.18	0.12	**0.98**	0.02	-0.04	0.04	0.95
Body mass index (kg/m^2)	18.3	1.9	-0.03	-0.21	**-0.94**	0.02	0.15	-0.02	0.95
Body mass – kg	47.8	12.0	0.34	-0.00	**-0.70**	0.01	-0.17	0.10	0.98
Right thigh girth – cm	47.9	4.9	0.12	-0.05	**-0.86**	-0.02	-0.02	0.11	0.94
Trunk length – cm	48.9	5.6	0.43	0.10	**-0.53**	0.01	-0.01	0.27	0.86
Right arm length – cm	71.6	7.3	0.45	0.11	**-0.47**	-0.00	-0.32	0.13	0.96
FACTOR OF ASYMMETRIC PUSH-OFF POWER									
Force ratio in the first and second parts of push-off – in %	127.1	28.0	-0.09	0.03	0.05	**0.93**	-0.04	0.16	0.92
Ankle elasticity – angle degrees	46.0	4.0	-0.01	0.03	-0.10	**0.61**	0.19	-0.30	0.51
MORPHOLOGICAL INDEX OF TAKE-OFF ROTATION									
Skijumping morphologics take-off index	194.6	4.6	0.32	-0.08	-0.14	0.03	**0.93**	0.21	0.81
Right leg length – cm	82.3	8.0	0.36	0.13	-0.39	-0.00	**-0.54**	0.07	0.99
Right thigh length – cm	38.0	3.8	0.38	0.19	-0.41	0.00	**-0.48**	0.07	0.95
Right shank length – cm	38.7	3.8	0.38	0.14	-0.41	-0.02	**-0.45**	0.14	0.96
SKI JUMPERS' AGE – years	17.4	3.4	-0.23	0.03	0.01	-0.01	0.10	**0.95**	0.69
% OF VARIANCE			**55.1**	**12.9**	**10.3**	**5.3**	**3.3**	**2.3**	**1.8**

DISCUSSION AND CONCLUSION: The results of the factor analysis made on a sample of 67 Slovene ski jumpers, aged 15 years and more, showed that the manifest structure of 35 variables was reduced to six latent factor dimensions. The results are interesting primarily because they reflect the specificity in expressing of individual factors, as it is conditioned by ski jumps i.e. their specific movement technique. The success rate in ski jumps is affected by the general morphological-motor factor (Jošt, B., Pustovrh, J., & Dolenec, M., 1998). In

analysing the push-off power in a ski jumper's take-off one has to consider the factor of explosive push-off power (Komi P. V. & Virmavirta M., 1997). Explosiveness of take-off is particularly important in the first phase of ski jumper's push-off. From the point of view of aerodynamics, the existence of two independent specific morphological factors has to be taken into account.

Both morphological specific factors of ski jumpers have a strong impact on the execution of ski jumping technique. The morphological take-off index plays an important role in achieving of rapid transition to flight. The morphological aerodynamic index plays an important aerodynamic role in the central phase of flight. Ski jumpers with higher aerodynamic index show higher potential capacity for successful execution of jump in the flight phase. This finding is of great importance in selection of talented jumpers and their training.

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