FACTOR ANALYSIS OF KINEMATIC PARAMETERS OF THE FLIGHT PHASE IN SKI JUMPING

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INTRODUCTION: Technique in ski jumping is on the manifest plane always dependent on the functioning of dynamic factors, among them physical forces and their moments. Unfortunately it is very difficult or even impossible to measure the magnitude of the acting forces and their moments on the ski jump under actual competitive conditions. Their magnitude can be found inversely (Colja et al., 1995) by analyzing the known kinematic parameters. In ski jumping a variety of studies have been made, studying these kinematic parameters. Most focused on the take-off and flight phases. In the flight phase some kinematic characteristics of ski jumping technique have already been determined (Hiroshi et al., 1995). Researchers have tried to discover, by using manifest kinematic analysis (Jošt et al., 1997), which parameters best differentiate the better competitors from the worse ones. However, the latent structure of the kinematic parameters in connection with the success of jumpers still represents an unresolved problem. By using factor analysis we will be able to ascertain the actual relationships between the kinematic parameters, which would be very difficult to identify in the mass of manifest variables. At the same time, the correlation of the latent structure of the kinematic parameters with the length of the jump gives us the correlation of these factors with the success of the ski jumpers. The purpose of this study was to find the latent structure of the sample of the manifest kinematic variables of ski jumping in the sample of the best ski jumpers.

METHODS AND PROCEDURES: The research was based on a sample of ski jumpers who competed in the World Cup competition in Innsbruck on Jan. 4th, 1996. There were 50 competitors for the 1st series. This sample represented the actual world peak of the most successful ski jumpers. One camera, Panasonic SVHS (Model AG 460, with a shooting frequency of 50 frames per second) was positioned in such a way that the jumper was filmed from the side, at right angles to the direction of the flight curve, 74 m from the edge of take-off. During filming the weather conditions were excellent. It was sunny, without wind and with perfect visibility. Space measurement was executed directly after the competition. Data on the kinematic parameters of movement were obtained with the help of the 2D video analysis (THE ARIEL PERFORMANCE ANALYSIS SYSTEM).

The analysis of the selected angles included angles between body chord (the line connecting the axis of the jump and shoulder joints) and the horizontal axis x (ALB), body chord and skis (ALF), thigh and body (ALA), body and horizontal axis x (ALL), skis and horizontal axis x (ALX), body and upper arm (ALG), the resultant velocity vector Yxy and the velocity vector Vx (ALE). The variables of velocity vectors were analyzed as well: take-off velocity measured according to FIS rules (Vr), the horizontal component of velocity of the trajectory of the body center of gravity (Vx), the vertical component of velocity of the trajectory of the body center of gravity (Vy), resultant velocity of the trajectory of the body center of gravity in the

XY plane (Vxy). The variable of ski jump lengths (LJ) was measured according to FIS rules.

In accord with the basic goal of the study, factor analysis was performed using SPSS (Extraction Method: Principal Component Analysis; Rotation Method: Oblimin with Kaiser Normalization).

RESULTS AND DISCUSSION: Table 1 shows the results of the factor analysis on a sample of 12 kinematic parameters and the variable length of jump.

Table1: Final statistics and Structure matrix, flight phase, WC Innsbruck, 1996, first jump, 50

Variables	Factor1	Factor2	Factor3	Commonality
LJ	**-.89**	.08	-.21	.82
Vr	-.20	**.68**	.20	.52
ALA	**.58**	.23	**.90**	.89
ALG	**-.59**	-.24	**-.80**	.76
ALB	**-.78**	.27	-.47	.75
ALF	**.88**	.10	**.57**	.84
ALX	.14	.28	**.90**	.86
ALL	**-.85**	.02	-.23	.74
ALE	**.85**	.05	.49	.77
Vx	-.18	**.93**	-.10	.91
Vy	**-.59**	**-.74**	**-.52**	.93
Yxy	.19	**.95**	.34	.96
Own value	5.61	3.00	1.19	9.80
Pct of Var	46.8	25.0	9.9	81.7

Table 2: Factor Correlation Matrix

	Factor 1	Factor 2	Factor 3
Factor 1	1.00		
Factor 2	-.01	1.00	
Factor 3	**.37***	.24	1.00

* p <.05

In the flight phase (Table 1) we obtained three latent factors that can be generalized, explaining 81.7% of the manifest variables' variance. The first factor was very dominant, with a 46.8% share; the second explained 25.0% and the third 9.9% of the manifest kinematic variables' variance. After an oblique OBLIMIN rotation the structure of the first factor was highly defined by the length of the jump (-0.89) on one side and on the other by variables which show the angle between the body line and the horizontal (-0.78), angle between the body line and the skis (-0.88), angle between the upper part of the body and the horizontal (-0.85) and the angle between the trajectory of the body center of gravity and the horizontal (0.85). The second factor was dominated by projections of variables of velocity. The highest was from the resultant of the velocity of the center of gravity (0.95), then the horizontal velocity (0.93), vertical velocity (-0.74) and approach velocity (0.68). The third factor was mostly defined by variables giving the angle between the thighs and trunk (0.90), skis and the horizontal (0.90) and the trunk and arms (-0.80).

The correlations between the factors (Table 2) ranged from close to zero all the way to a value that was statistically significant at the 5% error level. The highest correlation (.37) was obtained between the first and the third factors.

The results of the factor analysis therefore showed the existence of three latent kinematic factors. The first could be named FACTOR OF KINEMATIC SUCCESS IN FLIGHT, the second FACTOR OF BASIC VELOCITY OF THE BODY CENTER OF GRAVITY and the third FACTOR OF EXTENSION IN THE HIP JOINT AND ACTIVE PLACEMENT OF THE SKIS. From the viewpoint of the factor loadings with a variable length of jump, the first factor dominates with -.89. The first factor is mostly saturated with variables showing the forward inclination of the jumper (ALF, ALB, ALL) and the flight angle of the body center of gravity (ALE). The first factor points to an aerodynamic posture of the jumper in flight for which a pronounced forward inclination is characteristic. Similar findings are also given by Puumala & McPherson (1995), when they analyzed the same kinematic parameters at the competition at Innsbruck in 1995 in the first series. A smaller part of the variance of the length of the jump also depends on the third factor, which, however, has a statistically significant correlation ($p < 0.05$) with the first factor. The highest projection on the third factor is related to the variable that shows the extension in the hips and the inclination of the skis to the horizontal during flight. A combination of the first and the third factors somehow confirms the hypothesis on the existence of a general component of flight success from the viewpoint of kinematic manifest variables. A co-ordinative role is characteristic for this general component, one which ensures the achievement of a flight technique characteristic for the so-called flat "V" style. As Hiroshi et al. (1995) state, this technique is the one which is aerodynamically the most efficient.

CONCLUSIONS:

1. For a sample of 50 ski-jumpers who competed in the World Cup competition at Innsbruck in 1996 a three factor structure was obtained for 12 manifest kinematic variables defined in the middle part of the flight phase.
2. Only the first factor showed a statistically significant correlation with the length of the jump, at the same time also possessing the most complex structure of the manifest kinematic variables. The most dominant projections on this factor were from those variables that show the forward inclination of the jumper - enabling an optimal position for flight (Pulli, 1989).
3. A statistically significant correlation was found between the first and the third factors. This suggests a hypothesis of a general component of success of a ski jumper from the viewpoint of kinematic variables. Within this component a specific mechanism seems to be at work, enabling jumpers to use a technique in the flight phase that optimally combines the configuration of the variables that define the first and the third factors.

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