CORRELATION OF SOME KINEMATIC PARAMETERS WITH COMPETITIVE SUCCESS OF SKI-JUMPERS AT THE 1994 WORLD CHAMPIONSHIP IN SKI-FLIGHTS IN PLANICA

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INTRODUCTION

Ski-jumping technique is the basis of success in ski-jumping. On the manifest level we can study it from the kinematic or dynamic point of view, proceeding from the determinacy of movement equations (Vaverka, 1987). Jumping technique can be described relatively well by the movement equations or with a theoretical simulation of the inertial surrounding space, however, a very important path also exists for discovering the characteristics of ski-jumping by monitoring the actual competitive activity of the ski-jumpers.

The purpose of this research was to find the level of correlation of some kinematic parameters of ski-jumpers, who competed at the 1994 Planica ski-flights World Championship (K = 180m), with their successfulness defined as the length of the jump.

METHODOLOGY

The subject sample comprised of 28 ski-jumpers who competed at the 1994 Planica ski-flights World Championship. They were divided into three qualitative groups (above average - AA, n=7; average - A, n=14; below average - BA, n=7) according to their success measured by the length of the jump. For analysis of the jump technique the following kinematic variables were chosen, measured in the first jump (1) and the second jump (2), 8 m after the edge of the take-off table (position A) and 78 m after the edge of the take-off table (position B). ALE angle between the X axis and the resultant velocity vector (VLR) in the XY plane VLR resultant velocity of body and equipment center of gravity (TT) in the XY plane VLX horizontal component of the velocity of movement of TT VLY vertical component of the velocity of movement of TT ZHIT approach velocity, measured according to FIS regulations ALS angle between the skis in the XZ plane ALA angle between the trunk and the thighs in the XY plane ALG angle between the right arm and the trunk in the XY plane ALG1 angle between the right arm and the trunk in the XZ plane ALB angle between the "body-bow-line" (line joining the shoulder and ankle joint) and the X axis in the XY plane ALF angle between the "body-bow-line" (line joining the shoulder and ankle joint) and the skis in the XY plane ALN angle between the legs in the XZ plane ALX angle between the skis and the X axis in the XY plane ALO angle between the trunk and the skis in the XY plane ATT body weight ATV body height.

The data on the kinematic parameters was obtained with 3D video analysis (CONSPORT).

RESULTS

The resultant velocity of movement of the common body center of gravity (VLR) was greater at the second measurement position (78 m after the take-off table) - see table I - than at the first (8 m after the take-off table). The increase in velocity was only a little less than 6 m/s. If we also take the approach velocity as a resultant velocity of the common center of gravity then we find that it was a lot higher than the take-off velocity at 8 m after the edge of the table and somewhat lower at the point 78 m after the table position. This is a clear indication of a drop in velocity in the take-off phase and its renewed increase after a certain culmination point of the flight curve, which however, on the average, only slightly surpasses the approach velocity.

The results of the one-way analysis of variance show that the best parameter for differentiating the "quality groups" was the angle between the horizontal velocity (VLX) and the resultant velocity of the common center of gravity (VLR) - elevation angle - in the middle part of the flight. The best group flew with a smaller angle of elevation, the difference being about 1.5 degrees. The differences in the angle of flight were most certainly conditioned (see table 2) by the position of the jumper and skis during flight. Significant difference between the defined groups were also found for the angle between the "body-bow-line" and the skis (ALFB) and the angle between the axis of the trunk and skis (ALOB). The best jumpers had, on the average, the smallest angle.

Table 1: Coefficients of correlation between the length of the jump and the kinematic parameters, Means and standard deviations for kinematic variables

		AA		A		BA		
	r	Mean	SD	Mean	SD	Mean	SD	F prob.
ALEA1	-.05	18.80	0.84	18.88	1.00	18.70	0.77	0.92
ALEA2	.14	18.91	0.88	19.26	0.73	19.46	1.02	0.49
ALEB1	-.72*	35.18	0.87	34.36	0.52	33.82	0.56	0.00*
ALEB2	-.78*	35.33	0.35	34.64	0.43	33.85	0.71	0.00*
VLRA1	.18	24.15	0.24	24.23	0.39	24.27	0.88	0.89
VLRA2	.38*	24.36	0.28	24.26	0.46	24.56	0.70	0.48
VLRB1	.02	30.08	0.65	30.74	0.81	30.21	0.97	0.16
VLRB2	.06	29.56	1.25	29.78	1.09	29.55	1.21	0.88
VLXA1	.18	22.86	0.28	22.93	0.44	22.98	0.76	0.90
VLXA2	.36*	22.95	0.44	22.91	0.45	23.14	0.69	0.65
VLXB1	.24	24.58	0.64	25.38	0.73	25.10	0.78	0.06
VLXB2	.20	24.25	1.02	24.50	0.92	24.54	1.05	0.84
VLYA1	-.02	-7.76	0.32	-7.82	0.35	-7.78	0.55	0.92
VLYA2	-.32	-7.87	0.36	-7.97	0.29	-8.17	0.44	0.33
VLYB1	.44*	-17.32	0.46	-17.34	0.44	-16.81	0.64	0.08
VLYB2	.31	-17.17	0.66	-16.90	0.63	-16.46	0.70	0.15
ZHIT1	-.22	28.40	0.19	28.48	0.12	28.33	0.32	0.27
ZHIT2	.45*	28.44	0.29	28.70	0.16	28.74	0.14	0.01*

Legend: AA - above average group
A - average group
BA -below average group
Mean - arithmetic mean
SD - standard deviation
r - coefficient of correlation (* statistically significant at or below p=0.05, critical value r=0.36)
p -statistical significance of the difference between groups

On the basis of the magnitude of the coefficients of correlation we can, at least hypothetically, define the following tendencies of a successful jump. Maximize the resultant velocity in the first part of the flight (VLRA). Maximize the velocity of movement of TT in the horizontal direction (VLX), during the whole flight and especially in its first part. Decrease the angle between the "body-bow-line" and the X axis (ALB), especially in the middle part of the flight. Decrease the angle between the "body-bow-line" and the skis in all parts of the flight curve (ALF). Minimize the flight angle of elevation (ALE) in the middle part of the flight. Optimize the angle between the upper part of the body and the skis in the XY plane in the take-off phase and minimize it in the middle part of the flight (ALO). This requirement must be combined with the minimization of the angle between the skis and the horizontal (ALX).

Table 2: Parameters giving dimensions of the jumpers' movement

		BA		A		AA		
	r	Mean	SD	Mean	SD	Mean	SD	F prob.
ALSA1	.27	2.35	1.88	2.73	1.24	3.56	1.22	0.36
ALSA2	.09	1.85	0.71	2.17	1.27	2.15	0.93	0.80
ALSB1	.16	17.45	8.05	23.63	5.94	21.04	6.15	0.13
ALSB2	.50*	16.20	8.54	20.66	8.27	25.37	6.58	0.13
ALAA1	-.05	150.94	9.76	143.61	9.72	146.30	4.79	0.23
ALAA2	.19	139.30	6.91	143.37	11.66	146.4	9.73	0.43
ALAB1	.42*	167.0	18.44	171.63	4.08	175.61	6.49	0.31
ALAB2	-.03	172.13	3.94	171.75	7.61	171.07	3.43	0.95
ALGA1	-.40*	24.41	8.74	18.11	7.28	15.34	8.72	0.12
ALGA2	.16	9.43	7.07	16.07	11.05	17.32	9.44	0.25
ALGB1	-.15	6.93	3.10	7.22	3.64	5.24	4.24	0.50
ALGB2	-.15	11.20	10.17	6.76	3.39	9.10	7.86	0.35
ALG1A1	-.22	8.82	3.02	7.32	3.03	7.36	1.44	0.49
ALG1A2	-.14	7.81	2.66	8.29	3.36	7.08	3.20	0.72
ALG1B1	-.23	19.93	8.24	13.25	5.71	16.90	5.32	0.08
ALG1B2	-.13	14.83	10.48	16.10	7.57	12.05	5.91	0.54
ALBA1	-.07	44.28	3.85	43.66	3.78	44.18	3.33	0.92
ALBA2	-.16	45.27	4.01	42.91	4.49	43.14	3.11	0.45
ALBB1	-.57*	15.46	10.82	7.52	4.12	6.41	3.96	0.02*
ALBB2	-.08	10.83	5.81	11.88	4.57	12.15	4.24	0.86
ALFA1	-.31	29.55	4.73	29.41	8.01	36.66	9.86	0.18
ALFA2	-.23	36.18	9.47	31.78	8.29	30.52	6.69	0.40
ALFB1	-.39*	15.66	18.23	8.07	4.78	7.91	4.74	0.23
ALFB2	-.34	13.98	6.21	10.64	4.82	10.01	5.08	0.33

ALOA1 .39*	8.48	2.93	8.12	4.25	13.90	17.78	0.07
ALOA2 -.15	9.78	8.37	12.07	5.46	6.51	3.22	0.19
ALOB1 -.47*	12.05	14.18	5.95	4.38	3.47	4.50	0.13
ALOB2 -.53*	14.30	11.15	7.34	3.51	4.77	2.19	0.01*
ALNA1 -.02	2.71	1.96	2.90	1.34	2.68	0.82	0.93
ALNA2 .09	2.71	1.15	2.33	1.46	2.87	1.34	0.67
ALNB1 -.04	5.65	4.00	6.85	4.17	5.68	3.79	0.72
ALNB2 -.02	6.41	4.56	5.86	5.37	6.90	4.98	0.90
ALXA1 -.31	14.60	3.48	13.94	7.26	8.50	9.04	0.26
ALXA2 .16	10.80	4.46	10.99	6.16	12.52	5.23	0.80
ALXB1 -.21	5.15	6.19	3.36	2.65	3.87	2.36	0.61
ALXB2 -.11	5.15	4.00	3.78	2.42	4.27	2.50	0.60
ATV1 -.17	176.16	8.23	177.72	6.06	176.42	6.72	0.87
ATV2 .09	173.00	9.30	178.58	6.47	177.00	3.51	0.29
ATT1 -.34	66.65	8.78	66.72	3.50	63.21	5.72	0.50
ATT2 -.03	62.88	8.51	67.96	5.01	64.12	4.17	0.25

DISCUSSION

The results are in complete accord with theoretical definitions of the ski-jumping technique. In the first part of the flight - the take-off - the jumper must maximize the horizontal velocity and minimize the vertical velocity. Therefore he must - in the supported part of the take-off action - minimize the air resistance in the horizontal direction, minimize friction and optimize the vertical velocity of the take-off (Vaverka, 1987). This tendency is then preserved also in the middle part of the flight, where the jumper must minimize the angle between the horizontal component of velocity and the resultant flight velocity. The jumpers should therefore achieve a greater height of the flight curve in this part of the flight, which is in accord with the results of flight analysis on the 120 m ski-jump in Planica on a sample of 30 top world-class jumpers (Jost, 1994).

In this way the theoretical tendencies of optimizing aerodynamic moments of the forces at work, manifesting themselves in minimization of air resistance in the horizontal direction and maximization of air resistance in the vertical direction attest themselves automatically.

CONCLUSIONS

On a sample of 28 ski-jumpers that competed at the 1994 Planica ski-flights World Championship we found statistically significant correlation of some kinematic flight parameters with the length of the jump. The results are in complete accord with the theoretical definitions of the ski-jumping technique and at the same time confirm some findings of experimental research of the aerodynamic aspect of ski-jumping.

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