KINEMATIC CHARACTERISTICS OF SKI-JUMPING ON JUMPING HILLS WITH DIFFERENT CRITICAL POINTS

BOJAN JOST, FRANTISEK VAVERKA, MIROSLAV JANURA

FACULTY OF SPORT, LJUBLJANA, INSTITUTE OF KINESIOLOGY, UNIVERSITY OF LJUBLJANA, SLOVENIA

FACULTY OF PHYSICAL EDUCATION, LABORATORY OF HUMAN MOVEMENT STUDIES, PALACKY UNIVERSITY OLOMOUC, CZECH REPUBLIC

INTRODUCTION

The **take-off** of **ski** jumpers is a complex movement action camed out by **ski** jumpers at a precisely defined location in a short time. The complexity of the take-off depends greatly on the size of the jumping hill, or the basic approach velocity which defines to a great extent the inertial system of the acting forces and their moments. In the stage of the take-off there also occcur decisive differences in the successfulness of the **ski**-jumping technique performed.

The intent and goal of this research has been to study the differences in some parameters of the take-off measured on jumping hills of different sizes, and for three quality levels of ski jumpers.

METHODOLOGY

The research has been camed out on a sample of top ski jumpers, the participants in the world cup competitions in **1993/94,** and in the world championship in **ski** flights in 1994. The analysed subjects were divided into three quality groups according to the length of the jump (above average - B, average - M and under average - L):

Location	Competition	size of facility	B	M	L
Planica	word cup	K 90 m	(n=12)	(n=12)	(n=12)
Innsbruck	world cup	**K 112 m**	**(n=13)**	(n=15)	(n=15)
Planica	world championship in flights	K 185 m	**(n=12)**	**(N=11)**	**(n=11)**

The take-off was recorded in the part situated 5-6 m before the edge and 2 m away from the edge of the take-off platform. All variables that show the angles between individual body parts were defined and measured at the edge of the take-off platform. With a high-speed camera PANASONIC SVHS 025, exposure **1/1000 sec,** 50 shots per second. and over 2 D of analysis **(Vaverka** et al.. 1994) developed at the Laboratory of Human Movement Studies in Olomouc), the following variables have been obtained:

Legend:

LJ jump length measured according to the FIS rules

AV approach velocity measured according to the FIS rules

a c - angle between the shank and the take-off platform plane

a k - angle between the thigh and the shank

αT - angle between the top part of the body and the plane of the take-off platform

a A - angle between the arms and the take-off platform plane

a E - angle between the upper arm and the lower arm

a R - angle between the line forming a straight line between the ankle joint and hip joint and the plane of the take-off platform

a G - angle between the line forming a **traight** line between the ankle joint and the centre of gravity of the body and the plane of the take-off platform

αJ - angle between the resultant velocity (V) and the velocity in the direction of the take-off platform (Va)
V - final take-off velocity
Va - velocity in the direction of the take-off platform plane
Vt - velocity of a ski jumper in the direction perpendicular to the ground

The parameters αJ, V, Va and Vt have been defined on the basis of the observation of the common centre of gravity in the 6-m area before the edge of the take-off platform. For all variables, the basic statistics and single-factor analysis of variance has been performed.

RESULTS

Table 1: Basic Statistical Parameters of Variables Measured at Planica in **1993,** **Innsbruck** in **1994,** and Planica in **1994.**

		B		M		L	
		x	s	x	s	x	s
LJ	K90	91.42	4.93	82.25	1.20	73.38	5.42
	K122	102.77	4.43	91.7	2.19	83.2	3.6
m	K185	158.5	19.29	117.45	4.46	95.55	7.27
AV	K90	90.78	0.57	90.04	0.52	89.68	1.03
	K112	88.78	0.40	88.71	0.43	88.48	0.49
m/s	K185	102.2	0.93	102.55	0.45	101.85	0.55
Q1	K90	72.5	3.9	72.4	3.9	75.5	3.3
angle	K112	70.0	3.3	71.4	3.4	71.8	4.9
degrees	K185	69.3	5.5	70.0	5.6	71.0	6.3
Q2	K90	146.1	7.1	145.4	8.3	147.8	8.6
angle	K112	144.2	5.8	142.4	8.1	140.2	7.2
degrees	K185	137.6	6.9	136.0	4.7	136.0	10.0
Q3	K90	28.1	6.5	27.4	6.5	27.7	8.0
angle	K112	24.5	6.1	24.4	4.5	23.3	5.0
degrees	K185	19.1	5.9	22.0	5.1	24.3	5.0
Q4	K90	188.1	13.5	187.8	9.6	182.5	13.4
angle	K112	181.8	9.6	184.3	10.0	179.6	11.3
degrees	K185	184.5	11.1	183.5	8.5	180.8	11.7
Q5	K90	152.2	6.4	155.0	10.9	150.7	13.6
angle	K112	159.1	8.9	154.5	10.2	159.4	9.6
degrees	K185	157.6	7.7	160.8	13.3	159.8	8.4
Q6	K90	89.5	3.9	89.4	3.8	91.1	4.8
angle	K112	87.9	3.0	90.6	3.1	91.7	3.8
degrees	K185	90.3	3.9.	91.8	4.1	93.2	3.8
Q7	K90	75.0	3.3	74.4	2.7	76.0	2.7
angle	K112	73.4	2.3	75.1	2.0	76.1	2.8
degrees	K185	73.3	3.3	75.5	3.5	76.8	3.2
Q8	K90	5.2	0.4	5.3	0.7	5.0	1.5
angle	K112	5.7	0.7	5.4	1.0	5.7	0.5
degrees	K185	5.5	0.8	6.1	0.6	5.5	0.9
V	K90	25.23	0.23	25.17	0.19	25.03	0.28
	K112	25.91	0.15	25.89	0.18'	25.72	0.20
m/s	K185	28.98	0.31	28.97	0.16	28.81	0.26
Va	K90	25.12	0.23	25.06	0.19	24.91	0.28
	K112	25.78	0.15	25.77	0.17	25.59	0.20
m/s	K185	28.85	0.32	28.81	0.17	28.67	0.28
Vt	K90	2.30	0.19	2.37	0.28	2.36	0.30
	K112	2.56	0.32	2.42	0.47	2.53	0.24
m/s	K185	2.76	0.39	3.05	0.30	2.74	0.45

DISCUSSION

The lengths of jumps varied substantially with respect to the size of jumping hills and the quality group of the ski jumpers. Similar, yet not so marked tendencies have also been established in the approach velocity which was considerably higher on the highest jumping hill (K-185). The angle between the shank and the take-off platform plane (Q1) confirms again the basic law, i.e. the tendency to minimization of this angle. In general, this angle was smaller on the larger jumping hill. The angle between the thigh and the shank was in inverse relation to the size of the jumping hill, which was already found by Jo st in 1988 in the analysis of the takeoff (1) at the world championship in ski flights in Obersdorf in the year 1988, and in comparison of the results with those on smaller jumping hills. Such a tendency (Vaverka, 1992) is, of course, conditioned biomechanically by the requirement to minimize the air resistance force, which is also confirmed by the tendency indicated by the angle between the top part of the body and the take-off platform plane (Q3). On the largest ski-jumping hill, better performances are thus achieved by those ski jumpers whose value of the angle Q1, Q2 and Q3 is lower. The angles which refer to the position of the arms (Q6 and Q7) have shown no marked tendencies and differences both as regards the criterion of the size of jumping hills, as well as the quality level of the defined levels of groups. The need for largest possible transfer of the body centre of gravity towards the front is confirmed by the angles Q6 and Q7. Better ski jumpers transferred in general the centre of gravity more in the direction of movement, those on the largest jumping hill being the most active ones in this respect. Poorer ski jumpers kept the centre of gravity more backwards, so in the fly-up phase they needed more time and energy for the required rotation which enables the transition into the flight phase. For the angle which indicates the vertical elevation of the centre of gravity in taking off (Q8) it was not possible to establish any tendencies which would confirm the differences as resulting from the respective size of the jumping hill or the quality level of the defined groups of ski jumpers. Such a finding is also in high correlation with the results obtained in the analysis of the variable (Vt) which indicates the velocity of the take-off in the perpendicular direction to the take-off platform plane.

CONCLUSIONS

Based on the position of individual body parts at the edge of the take-off platform the results of the research have shown that in ski-jumping, ski jumpers are basically discriminated as regards their performance according to the so-called aerodynmic aspect of the take-off defined by the moments of aerodynamic forces. The size of the jumping hill affects, however, to a minor extent the technique of the take-off, yet the differences were minimal and statistically irrelevant. The ski jumpers must thus create a refined technique of movement by which they will minimize air resistance in the direction of movement in the take-off phase and at the same time also satisfy the demand for accuracy of the take-off and achieving of optimal vertical velocity of the takeoff.

REFERENCES

Jost, B.: The Relationship between Some Kinematic Parameters of a Ski-Jumper's Take-Off and his Performance at the World Championships in the Olympic Year 1988, Sport 38 (1990) 3/4, 39-45.

Vaverka, F., Janura, M., Kr skova, M., Salinger, J.: TheAccuracy of the Ski-Jumper's Take-off. In: Proceedings ISBS'92, Milan-Italy, 1992, 319-322.

Vaverka, F., Elfmarak, M., Janura, M., Kr skova, A.: Kinematic Analysis of Ski-Jumping. Software and Manual, Olomouc, 1994, 109 pp.