KINEMATIC-DYNAMIC ANALYSIS OF THE TAKEOFF ACTION IN LONG JUMP

Milan Čoh, Otmar Kugovnik, Aleš Dolenec
Faculty of Sport, University of Ljubljana, Slovenia

INTRODUCTION

The kinematic model of long jump consists of four interdependent structural units: approach, takeoff, flight and landing. According to previous studies (Popov 1983; Hay, Miller, Canterna 1986; Brüggemann & Susanka 1987; Hay 1987; Nixdorf & Brüggeman 1990; Lees, Smith & Fowler 1994) the approach and the takeoff action are the most important factors affecting the long jump results. The most basic problem of long jump is therefore an optimal transformation of the horizontal velocity the jumper develops during approach into the takeoff velocity at takeoff. The length of the jump is - according to the kinematic model (after Hay, 1986) - defined by the height of the CM at takeoff, takeoff angle, takeoff velocity, takeoff distance, length of flight and the landing distance. The takeoff angle and takeoff velocity which define the flight parabola of CM depend in turn on the horizontal and vertical velocity of CM at takeoff.

The purpose of this study was to identify those dynamic and kinematic parameters of the takeoff action which most affect the long jump results of top jumpers.

METHODS

Subject sample

The subject sample comprised of 24 long jumpers from the Republic of Slovenia, who competed at the three most important competitions in 1994. Their best attempt was used.

Measurement procedures

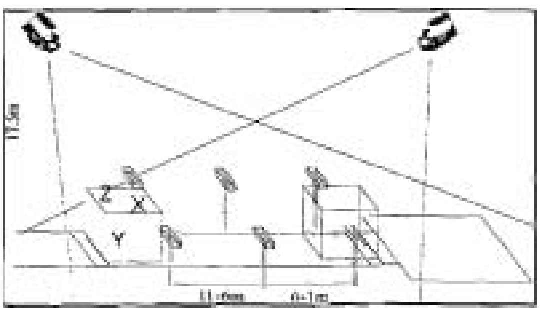

Figure 1 - Position of video-cameras and photo-cells

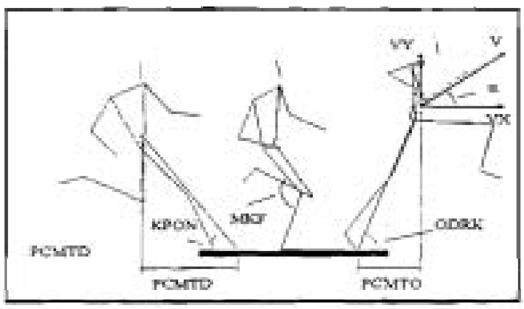

Figure 2 - Kinematic-dynamic parameters of the takeoff action (touchdown, maximal amortisation, takeoff)

For assessing the dynamic and kinematic parameters a 3-D video kinematic system was used - the CONSPORT (CONSPORT MOTION ANALYSIS SYSTEM) - and a system of photocells to measure the approach velocity from 11-6 m and from 6-1 m prior to the takeoff board. Two video cameras (PANASONIC SVHS) were placed at an angle of 90° to the takeoff board at a distance of 17.5 m (Fig. 1). The co-ordinate system was defined by the X-axis (horizontal), Y-axis (vertical) and Z-axis (depth). A biomechanical model of a jumper was used, defined by seventeen points. In the kinematic procedure. the parameters of the last

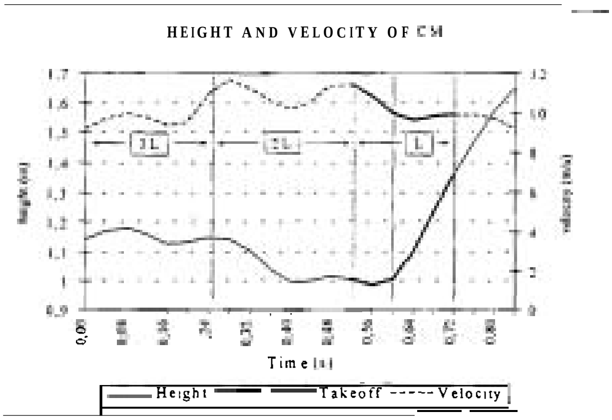

Figure 3 - Trajectory and velocity of CM

three steps were analysed and also the parameters of the takeoff action (Fig. 2 and 3). In further analysis the following statistical procedures were used: basic statistics, Student t-test to assess the differences between the two groups and correlation analysis to find the correlation between the parameters of the takeoff action and the long jump results.

Parameters

OFFI	- official distance (cm)
EFFI	- effective distance (cm)
DIF	- difference between OFFI and EFFI (cm)
3L	- length of 3rd last stride (cm)
3L	- length of 2nd last stride (cm)
L	- length of last stride (cm)
V11-6	- velocity from 11-6 m prior to takeoff board (m/s)
V6-1	- velocity from 6-1 m prior to takeoff board (m/s)
VX	- horizontal velocity of CM at takeoff (m/s)
VY	- vertical velocity of CM at takeoff (m/s)
V	- takeoff velocity (m/s)
α	- takeoff angle (degrees)
HCMTD	- height of CM at touchdown (cm)
HCMTO	- height of CM at takeoff (cm)
RCM	- difference in height of CM from touchdown to takeoff (cm)
KPON	- angle between the line joining the CM to the toe and the forward horizontal plane at the instant of touchdown (degrees)
PCMTD	- projection of CM at touchdown (cm)
PCMTO	- projection of CM at takeoff (cm)
ODRK	- angle between the line joining the CM to the toe and the forward horizontal plane at the instant of takeoff (degrees)
MKF	- max. amortisation in the knee of takeoff leg (degrees)

RESULTS AND DISCUSSION

Beside the procedure for finding the correlations between parameters of the takeoff action and the long jump results. we were also interested to see in which parameters the jumpers differ the most (statistically) if we divide them into two sub-groups of different quality. This information is given by table 1 where the differences between the better-jumper group (n=14) and the worse-jumper group (n=10) can be seen. Statistically significant differences ($p<0.01$) exist in maximal horizontal velocity (V6-1), length of 2nd last stride (2L), projection of CM on the surface at the time of placement of the takeoff leg (PCMTD) and accurately of the approach (DIF).

The rhythm of the last three strides of better jumpers is such that the length of the 2nd last stride is longer than that of the last stride. For the worse-jumper group in our sample the last stride was, on the average. 34 cm longer than the 2nd last stride. This shows the inferior level of technical readiness of jumpers in this group, especially in the preparation for the takeoff action phase. The difference between the official length of the jump (OFFI) and the effective length (EFFI) is 8 cm for the better group and more than 18 cm for the worse group. A significant difference between the groups was also noted in (V6-1) - 1.02 m. The approach velocity obviously generates the differences in the speed of the takeoff action, resulting in vertical and horizontal velocity at takeoff (VX and VY). The values of the horizontal and vertical velocity of CM are very similar to those obtained in other studies (Popov, 1983; Lees et al.. 1994).

Table 1: Correlations between predictors and the criterion, differences between the groups

	N= 24					N= 14		N= 10		
Parameters	X	SD	MIN	MAX	r	X	SD	X	SD	t
OFFI	718	56.4	582	800		757	30.5	664	35.2	0.000**
EFFI	729	50.0	607	805		763	27.6	682	32.5	0.000**
DIF	13	7.4	2	25	-0.74**	8	6.1	18	5.2	0.001**
3L	213	21.9	165	249	0.43*	219	20.9	206	22.2	0.338
2L	230	23.5	183	276	0.39	241	19.2	213	19.4	0.002**
L	238	24.5	204	288	-0.18	231	21.2	247	26.9	0.118
V11-6	9.19	0.4	8.47	10.43	0.44*	9.49	0.5	9.00	0.3	0.050*
V6-1	9.59	0.6	8.97	10.87	0.88**	10.13	0.6	9.11	0.2	0.000**
VX	8.69	0.7	7.51	9.95	0.44*	8.95	0.6	8.32	0.5	0.022*
VY	3.20	0.4	2.21	4.14	0.59**	3.35	0.3	3.01	0.4	0.050*
V	9.77	0.6	7.98	10.51	0.58**	9.56	0.5	8.86	0.5	0.004**
a	20.1	2.7	14.0	75.7	0.37	20.6	2.8	19.4	2.6	0.341
HCMTD	0.97	0.6	0.89	1.14	0.14	0.99	0.7	0.94	0.4	0.058
HCMTO	1.18	0.8	1.03	1.36	0.43*	1.22	0.8	1.15	0.6	0.050*
RCM	22	0.5	14	32	0.11	23	0.8	21	0.4	0.358
KPON	54	6.3	59	67	0.01	55	4.6	53	8.2	0.435
PCMTD	53	0.2	27	SD	0.64**	60	0.2	43	0.1	0.007**
PCMTO	29	0.1	12	45	-0.02	77	0.1	31	0.6	0.557
ODRK	74	6.4	60	89	-0.45*	72	7.6	77	4.4	0.084
MKF	146	11.5	122	169	-0.20	145	9.8	148	13.9	0.568

X - arithmetic mean; SD - standard deviation; r - coefficient of correlation; t - statistical significance of the difference between groups; ** $p<0.01$; *$p<0.05$

Takeoff velocity, as one of the most important predictive parameters of successful long jumping, statistically significantly differentiates the two groups. The difference in means is more than 1.2 m/s. The takeoff velocity of the better group is 9.56 m/s, of the other 8.86 m/s.

The position of the jumper at the moment of placement of the takeoff leg on the surface is also different between the two sub-samples. Better jumpers have statistically significantly greater PCMTD on the surface in regard to the point of contact of the takeoff leg on the surface (7 cm difference), while this parameter also affects the realisation of a greater VY.

Inspection of the correlation coefficients (table 1) shows us that ten kinematic-dynamic parameters have a statistically significant correlation with the long jump results. The highest coefficient (r=0.88) is found for V6-1 which the jumper manifests 6-1 m before takeoff. A somewhat lesser correlation (r=0.69) was obtained by Nixdorf & Brüggemann (1990) on a sample of eight finalists of long jump at the Olympic Games in Seoul. A generally positive correlation between the long jump results and the maximal approach velocity for jumpers of different quality was obtained in the majority of such studies (Popov, 1986; Hay, Miller & Canterna, 1986; Brüggemann & Susanka, 1987). Maximal approach velocity also generates adequate vertical and horizontal velocity of CM at takeoff, these being dependent on the placement of the takeoff leg on the surface, maximal flexion of the knee of the takeoff leg, compression phase and the resultant of elastic power (Lees et al., 1994). The correlation of approach velocity and VX is 0.67. the correlation with takeoff velocity (V) is even 0.75.

PCMTD on the surface at the time of placement of the takeoff leg on the board is, judged by the value of correlation 0.64, the second most important kinematic parameter which affects the long jump results. The position of the jumper at the time of placement of the takeoff leg on the surface generates VY, the correlation being 0.52. The vertical velocity is according to prior studies (Hay, Miller, Canterna 1986; Lees et al. 1990) the key factor which, together with VX, defines the takeoff velocity (V) and the takeoff angle (α) of the jumper. The correlation between VY and α is 0.86. The takeoff velocity has a medium correlation with the criterion r=0.58. This is a little lower than the 0.83 found by Hay, Miller, Canterna (1986).

An effective takeoff action is an optimal combination of the magnitude of the vertical and horizontal velocity of CM. Both parameters have a statistically significant correlation with the long jump results (VY r=0.59, VX r=0.44). Ensuring vertical velocity has the unavoidable consequence of lessening the horizontal velocity, but this reduction should be as small as possible. The VY is generated mainly by the horizontal velocity in the compression phase, depending mainly on the placement of the takeoff leg (KPON) and MKF (Lees et al., 1990). In our study the second parameter did not have a positive correlation with the long jump results. The average value of the angle of maximal amortisation in the knee was 146°, which is in accord with the results of some prior studies (Popov 1983, Hay & Nohara 1990).

A low, but statistically significant correlation was found between the criterion and the ODRK (r = -0.45). The mean value of this parameter for our jumpers was 72°. Other studies (Popov, 1983; Hay et al., 1986) also lead us to the conclusion that this parameter does not have a very significant predictive role for long jump.

CONCLUSION

The jumpers differ most in view of the achieved results (EFFI was used as a criterion) in: maximal approach velocity, accurately of placing the takeoff foot in relation with the takeoff board, the projection of CM at the time of placement of the takeoff leg, length of the last stride and takeoff velocity.

From the results of correlation analysis we can conclude that success in long jump depends mainly on: maximal approach velocity 6-1 m prior to the takeoff board, the projection of CM at the time of placement of the takeoff leg, takeoff velocity of CM, horizontal and vertical velocity of CM. The research has theoretical as well as practical value, as it gives a coach the means for a more objective and rational planning and monitoring of the training process of long jumpers, by using relevant parameters.

REFERENCES

1. Bosco, C. (1985). Stretch-shortening cycle in skeletal muscle function and physiological considerations on explosive power in man. Atleticastudi, Fidal, Centro Studi & Ricerdche, Roma 1.
2. Hay, J.G., Miller J.A. & Cantema, R.W. (1986). The techniques of elite male long jumpers. Journal of Biomechanics, 19, 855-866.
3. Hay, J.G., & Nohara, H. (1990). Techniques used by elite long jumpers in preparation for take-off. Journal of Biomechanics, 23, 229-239
4. Lees, A., Smith, G.. & Fowler N. (1994). A Biomechanical Analyses of the Last Stride, Touchdown, and Takeoff Characteristics of the Men's Long Jump. Journal of Applied Biomechanics, 10, 61-78.
5. Nixdorf, E., & Brüggemann P. (1990). Biomechanical analysis of the long jump. Scientific Research Project the Games, of the XXIVth Olypiad-Seoul 1988. International Athletic Foundation.
6. Popov,V.B. (1983). Long Jump. Physical Culture and sport, Moscow.