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Biophysics

Contribution of Certain Biomechanical Parameters to the Results of Long Jumps

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ABSTRACT. In this article we perform theoretical analysis of long jumps with the purpose to find the contribution of different biomechanical parameters to the final results. The graphical diagrams show how the result changes when the parameters change. The calculated diagrams may be useful for trainers and athletes in order to predict and improve their achievements. *© 2009 Bull. Georg. Natl. Acad. Sci.*

***Key words**: biomechanical analysis, video-computer modeling, long jumps.*

In the recent publications [1-4] we presented a new markerless method for video-computer modeling based on the well-known principle of forward kinematics. This method was successfully applied to video-computer modeling of long jumps [2, 4].

The method may be more effective when combined with a well- developed theoretical model. In this article we investigate how the result of long jumping depends on the basic parameters which characterize the push-off phase, namely, on the value and direction of the sportsman's start speed and the start point coordinates. The start point is the position of the sportsman's center of gravity at the push-off moment when his pushing-off leg comes off the ground. The motion of the sportsman's center of gravity in the gravitation field can be described by the following formulas.

$$L= L_0 + L_1+ L_2; \tag{1}$$

$$x_0= L_0= r \cos\beta;\ y_0= r \sin\beta;\ r = (x_0^2+ y_0^2)^{1/2}; \tag{2}$$

$$V_{0x}=V_0 \cos\alpha;\ V_{0y}=V_0 \sin\alpha; \tag{3}$$

$$T_1=V_{0y}/g\ ;\ y_1=H_{\max}=y_0+V_{0y}^2/2g; \tag{4}$$

$$T_2=(2(y_1-y_2)/g)^{1/2}=(2(y_0-y_2)+V_{0y}^2/g^2)^{1/2}\ ; \tag{5}$$

$$L_1=V_{0x}\times (T_1+T_2\ ), \tag{6}$$

where V_0 is the start speed of the sportsman, V_{0x}, V_{0y} are x, y projections of V_0, α is the angle between OX and V_0, (x_0, y_0) is the start point, r is the length of the radius-vector of the center of gravity at the push-off moment, β is the angle between r and OX , (x_2, y_2) is the end point, (x_1, y_1) is the highest point, T_1, T_2 are time intervals from the start point to the highest point and from the highest point to the end point, respectively, and L is the motion along x axis;

$$T=T_1+T_2; \tag{7}$$

$$X(t) = V_{0x}\ t;\ Y(t) = V_{0y}\ t - g\times t^2/2; \tag{8}$$

$X(t)$, $Y(t)$ are time dependences of coordinates of the center of gravity, T is the total period of motion. In these formulas we do not consider the contribution of air drag, which decreases the result by about 3-4%.

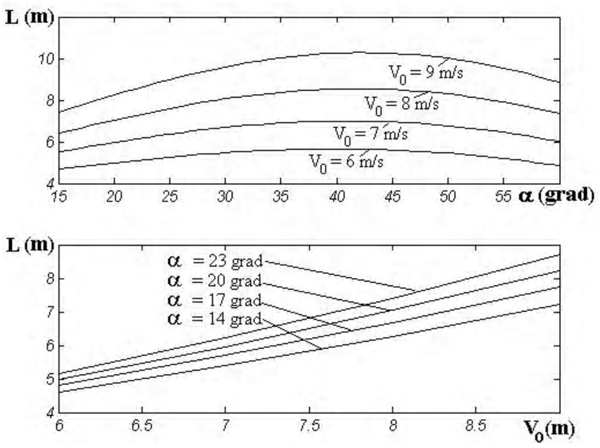

Fig. 1. Dependences of the result L on V_0 and α (r = 1.5 m, β = 60°, $L_2 = y_2$ = 0.5 m).

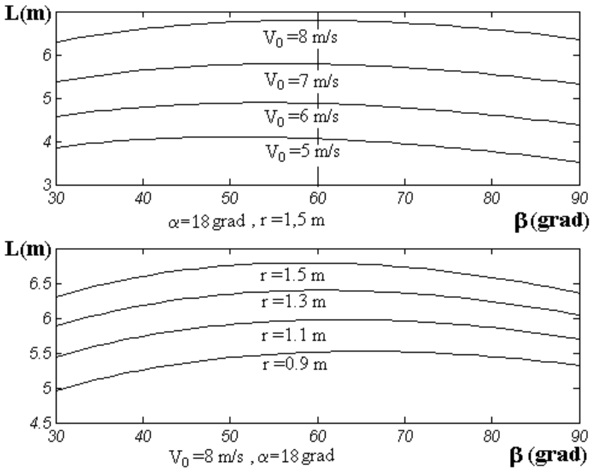

Fig. 2. Dependences of the result L on β, V_0 and r ($L_2 = y_2$ = 0.5 m).

Obviously L strongly depends on two parameters: V_0 and α. L increases as V_0, α increase. In Fig.1 there are shown dependences of L on α and V_0, which have almost linear character in the actual range of V_0 – 6-9 m and α – 15-30°. Increasing of α from 15° to 20° improves the result by 1 meter (V_0=8 m/s), and increasing of V_0 from 6 m/s to 9 m/s improves the result by 3 meters (α=20°). Increasing of speed by 1.0 m/s is equal to increasing of α by 6-7°. We see that the dependence of L on V_0 is much stronger than on α.

At the same time, there exists a comparatively slight dependence of L on β and r: from Fig.2 we see that optimal values for β are between 50 and 70°, r depends basically on the sportsman's body proportions, length of his legs, height and relative positions of his body parts at the push-off moment. Tall sportsmen with long legs will have greater value of r.

From earlier experimental data for three sportsmen with different qualifications [2, 4] we found corresponding values of r and β, which are presented in Table. As one can see, the sportsman with high qualification has the best values almost of all parameters. For example, he has significantly higher value of r than the other sportsmen.

Conclusion. In our work we show how the results of long jumps depend on certain parameters which characterize the push-off phase. Fitting a theoretical graph of the sportsman's center of gravity to the experimental points may help to find the values of the main parameters more exactly and discover the weaknesses of the sportsman.

From the theoretical dependences presented in Figs. 2,3 the trainers and sportsmen can get useful information quickly even without performing video-

Table.

Experimentally obtained values of the main parameters

N	Qualification	V_0, m/sec	α, °	β, °	r, m	H_{max}, m	L, m
1	High	8.27	19.62	71	1.57	1.91	6.70
2	Medium	8.45	14.19	70	1.4	1.54	5.70
3	Low	7.13	23.1	68	1.23	1.43	4.82
4	High	8.46	24.91	70	1.6	1.92	6.52
5	Medium	7.62	17.64	68	1.47	1.52	5.62
6	Low	7.11	18.05	71	1.26	1.37	4.94
7	High	8.75	18.2	68	1.63	1.88	7.02
8	Medium	8.85	17.49	73	1.42	1.63	5.74
9	Low	6.85	21.13	69	1.32	1.46	5.01

computer modeling.

The analysis also provides a criterion for selection of long jumpers: tall sportsmen with long legs are more prospective.

Summarizing all the above said we can conclude that video-computer modeling combined with theoretical biomechanical analysis is a reliable way to improve athletic achievements.

ბიოფიზიკა

ზოგიერთი ბიომექანიკური პარამეტრების გავლენა სიგრძეზე ხტომის შედეგებზე

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