A METHOD FOR DETERMINING THE INDIVIDUAL SPORT TECHNIQUE IN JAVELIN THROWING BASED ON A DISCRIMINANT ANALYSIS

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INTRODUCTION.

The javelin throwing is a movement which objective is to reach the maximum velocity of human body chain free end at the release instant. Obviously, The release speed will be maximun depending on the precedings movements, especially, of those defining the throwing phase. The throwing phase begins with the last double feet contact and finishs with the release of the javelin. During this short time (100-200 ms) the bigest increasing of the javelin speed is produced. According to the majority of the authors, this period is divided in two parts. During the first one, the thrower turns the hips and shoulders consecutively through the longitudinal axis of the trunk, while, the javelin should remain to the rear so that the right shoulder, the upper arm and the elbow move upward-forward. At last of this part, an "arched position" must be reached (Koltai, 1985). In according to Ikegami (1981), the kinetic energy of the thrower is body obtained during the approach run may be stored as an elastic energy in the earlier part and then released to accelerate the javelin in the later part, that is in the acceleration phase. The acceleration phase starts with the "arched position" and finishs with the javelin release. The energy is restored beginning by the trunk and following by the upper arm, under arm and javelin. In fact, It has been proved for numerous researchers that during the throwing phase the segments reach the maximum speed consecutively and beginning for the proximal segments (Whiting, 1991). This one has done to think that throwing pattern is based in the energy transmission among segments. However, nobody has found until to day cuantitative relations among energy exchanges which allow to establish, in an objective way, differences among throws of one subject.

In relation to the lack of information about the contribution of the trunk, must be taken into account that this segment has been considered normally like a bar, that is, no differing thorax, abdomen and pelvis. Finally, to remark that it has not been found any research which calculates the kinetic energy of segments considering them with their six degrees of freedom. **Therefore, the main objective of this work will be to develop individual technique patterns based in the energy exchange among segments. This model should allow to assess the performance objectively.**

METHODS.

Definition of a theorical model of the kinetic energy. The model considers that the system (human body + javelin) is composed of 6 rigid solids (thorax, pelvis, upper arms and thighs) and 11 bars (head, abdomen, under arms, hands, legs, feet and javelin). The bars are defined by two points; the thorax and pelvis by three. The upper arms and thighs are defined by two points; the elbow and knee joints are

considered with 1 degree of freedom. Therefore, the system movement is determinated by 26 markers. The algorithm through which the kinetic energy of the segments are calculated is based in the next items:
i) A Local Reference System fixed with the segment is determined.
ii) The rotation matrix of the Local Reference System is determined in relation to the Inertial Reference System.
iii) The inertial parameter (mass, location of center of mass and inertial momentums) of the segments are calculated using the Zatsiorsty (1983) and Clauser (1969) data.
iv) The kinetic energy is calculated considering it like the addition of a traslational and a rotational terms.

Experimental technique. The experimental technique was the photogrammetry. The subjects were the two best spanish throwers. A total of 36 throws were analyzed. The distance range was 59-66 for subject A and 58-68.9 for subject B. Two cine-camaras were used at a frame of 200 Hz. The three-dimensional co-ordinates of the 26 points which defined the body model were obtained using DLT algorithm.After computation of the thrower's center of mass co-ordinates, the data were smoothed using quintic splines. The energy increments of the segments between the instants in which the thowing phase was divided, were the variables. With these variables a correlational and discriminant analysis was carried out considering each subject separately.

RESULTS.

The kinetic energy increments of the segments and groups of segments were calculates -for each throw- between the next time instants (Figure):

- t_1. Left foot contact (beginning of the throwing phase.
- t_2. Arched position (external rotation maximum of right upper arm).
- t_3. Kinetic energy maximum of upper arm.
- t_4. Kinetic energy maximum of right under arm + right hand.
- t_5. Javelin release.

1. Mechanical pattern. With the objective of analyzing the mechanical behaviour of each thrower, a correlational study was carried out. The results for the subject RF showed that during the first period (t_1,t_2), the body performs divided in two parts: the lower part (lower members + trunk) and upper part (upper arm + under arm + hand). Direct relations were founds among the segments within these parts (Table); this one did to think in a whole behaviour of each group. Inverse relations (Table) among the segments of the two parts showed a possible energy exchange between them. For instant, as the increment of energy of the lower members is smaller (this variable is negative) biger is the increase of the right upper arm ($\rho = -0.57$, $p< 0.05$) during the (t_1,t_2) period. During the acceleration phase (t_2,t_5), a kinetic energy exchange among segments was proved (Table).

$t_1 - t_2$	Lower members-trunk	$\rho = 0.57$, $p< 0.01$
$t_1 - t_2$	upper arm-javelin	$\rho = 0.79$, $p< 0.01$
$t_1 - t_2$	Lower members-upper arm	$\rho = -0.57$, $p< 0.05$
$t_2 - t_3$	Lower members-upper arm	$\rho = -0.89$, $p< 0.01$
$t_3 - t_4$	upper arm-javelin	$\rho = -0.69$, $p< 0.01$
$t_4 - t_5$	upper arm-javelin	$\rho = -0.73$, $p< 0.01$

2. Individual pattern of throwing. For studing the individual technique of throwing a Factorial Discriminant Analysis was carried out. For this matter the throws perfomed for each athete were divided in two groups; the best throws in the group 1 (more distance than the median distance) and worse throws in the group 2 (less distance than the median). In the case of the subject RF the discriminant analysis presented a canonical correlational coeficient of 0.77 ($p<0.05$). This showed the existence of a significant discriminant function which allows differentiate objectively between the throws of the groups 1 and 2 (best and worse throws). In a way of that the function was biger (positive) when the throws correspond to the group 1 and smaller (negative) for the group 2. The Discriminanr function was:

Fd= - 0.15791 VAR1 - 0.00251 VAR2 + 05841 VAR3 - 16.6464

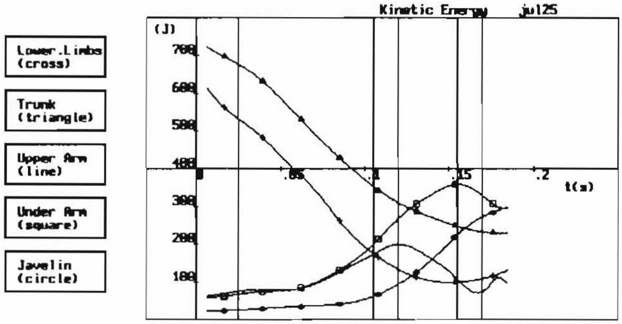
VAR1: Sum of the normalized increment of the kinetic energy of the lower member and trunk in the (t_1,t_2) period (negative variable).

VAR2: Sum of normalized increments of the right upper arm, under arm, hand and javelin in the (t_1,t_2) period (positive variable).

VAR3. Sum of the normalized increments of the right upper arm and the absolute value of the lower members in the (t_2,t_3) period (positive variable).

The discriminant function shows the individual pattern of movement in which the subject is basing his performance. Through this function is possible to evaluate objectively the individual technique of any throw:

1. During the earlier part since the beginning until to reach the arched position, (t_1,t_2) period, the subject performs good thows (FD >0) when decreases a lot the kinetic energy of the lower members (higher negative value of VAR1) and the increase of the energy of the upper arm is smaller (less positive value of VAR2). That is, in this thrower the correct performing of the arched position is a key for distinguishing between good and bad throws. Therefore, in relation to the (t_1,t_2) period, we can assert that the technique of this athete is good enough.
2. In the (t_2,t_5) period, the function take positive values when the VAR3 is higher, that is, when the absolute value of the decreasing lower members kinetic energy is biger at he same time that the increasing of the kinetic energy of the right upper arm is also higher. This shows that the subject performs goods throws when there is a energy transmission from the lower member to the upper arm. This can confirm the importance of the performing correctly a secuence of movements in which the proximal segments decrease their energy before the distal segments increase it.



In the case of the subject JS, a significant discriminant function was also found. This function was different to the earlier case showing, therefore, a different individual technique of throwing.

CONCLUSIONS.

1. A kinetic energy model which considers the main segments with six degrees of freedom has been developed.
2. This model is compatible with photogrametric techniques and can be used for analyzing the human movement.
3. The mechanical pattern of throwing based in the energy exchange between segments has been proved objectively -not in a especulative way like normally has been done- in the two analyzed athetes.
4. A procedure based on the statistical technique known by discriminant analyisis has been developed for evaluating the individual sport technique in a cuantitative way.
6. The existence of a individual pattern of throwing has been proved for each subject. These patterns were differents in despite of the mechanical behaviour was the same in the two athetes.
5. This procedure allowed to evaluate objectively the quality of the throws performed by the two subjects. By mean a linear function, the key points of the performance of each thrower could be showed cuantitatively and, therefore, the technique was evaluated objectively.

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