# Biomechanics of a Motor Pattern and its Sports Application

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## INTRODUCTION

Man is capable of acquiring an ever increasing number of motor responses and in this way to improve his relationship with the environment. Obviously, if it was necessary to create a new motor organization for each new situation, the human motor behaviour would be chaotic for the sheer number of motor responses which would have to be available for ready utilization. Indeed, it is easier for the central nervous system to adjust to new environmental conditions and to different goals by compounding new motor programs from previously learnt subroutines. These subroutines — the motor patterns — evolve during the performer's life through general learning and specific training processes.

The pattern approach to the motor organization is not new. Broer (1966) relates the shape of the movement with the skill goal and gives a set of examples with different goals but for which the shape is conserved. Wickstrom (1977) calls these shapes «Movement patterns». Obviously, similar limb kinematic relationships correspond to similar kinetic relationships, a fact already pointed out by Higgins (1972) when he states that each motor skill consists of three - motor, muscular and movement - components. According to Wickstrom the development of each skill is an extensive process focused successively upon three major steps: the minimal form, the mature form and the sport skill form. The core of the mature form is the fundamental motor pattern. The sport skill is adapted to special requirements by the rules or by the strategy of each sport.

From a mechanical point of view the human body «is» an articulated link system which simultaneously behaves as a rigid one when it resorts to external support to achieve the mechanical energy flows envolved in a desired performance. The efficiency of such a performance is determined by the mechanical work of the limbs but its final effect can be deduced from the knowledge of the center of mass kinematics and of the force exerted on the support. The motor organization may thus be conceived as integrating two simultaneous mechanical behaviours: an articulated link system relatively to the limb movements and a rigid system relatively to the external environment. Indeed if the human body behaved strictly as a «rigid system» it would have the tendency to rotate about the center of the support by an amount which would be proportional to the energy it possessed. In reality this does not occur and, instead, the system performs a set of intersegmental movements in accordance with the goal proposed for the desired skill and the result of this «articulated» behaviour is transferred to that of the «rigid» mode.

Two complementary approaches to the biomechanical study of human motor patterns are thus available: the evaluation of the internal work performed by the limbs and the dynamical analysis of the center of mass of the «rigid body» system.

## NUMERICAL MODELLING OF THE JUMPING FOR TWO DIFFERENT GOALS

The fundamental purpose of the jumping is to confer to the axis joining the center of mass and the center of the support, the rigidity which is necessary to make the mechanical behaviour of the human body resemble that of a rigid system.

In ideal mechanical conditions a perfectly elastic body colliding with a perfectly rigid support would follow a rebound trajectory for which the landing and take-off velocity vectors would have the same inclination relatively to the vertical. A stimulated living body will have a similar behaviour if its limbs perform adequately. The articulated body, however, has the possibility of modifying the characteristics of the take-off velocity vector in order to achieve a pretended goal and which may be quite distinct from a simple elastic rebound.

The work performed by the articulated limb system during the period of contact with the support, work which is crucial for the achievement of the right take-off velocity vector characteristics, has important implications regarding the contact time and the energetic efficiency.

## Model Characteristics

The model we have formulated represents the performer as a set of forteen pin articulated link segments defined from two-dimensional cinematographic images and is therefore non-intrusive. The computation of the center of mass of the different segments was based on the data from the Demptser table and the equations describing the displacements as a function of time were obtained by third order polynomial least square interpolation.

## Methods

Two groups of performers were organized: one, designated the «S» group, constituted by the best three female and three male long jumpers in the country and another, designated the «N» group, constituted by an equal number of physical education students. All the performers repeated four times two different jumps defined by their respective goals: the «C» jump was to be the «longest possible» and the «A» jump to be the «highest possible». The «S» jumpers are experienced in performing the «C» jumps and the «N» jumpers are familiar with this skill; both groups of performers are not familiar with the «A» jump and we assume that they all have to adapt the jumping pattern to this situation. A total of ninety six jumps were performed.

The supported phase of the jump was executed on a kistler force platform connected to a digital oscilloscope. The cinematographic data were obtained with a paillard bolex cinecamera at 52 frames per second. The frames were digitized with the help of a lafayette MKVI projector and a houston instruments digitizer connected to a digital PDP-11/24 minicomputer. From these data the graphic model of each performer, the trajectories of the center of mass of the whole body were obtained, the trajectories were interpolated by a third degree polynomial for the supported phase and a second degree polynomial for the flying trajectory. The velocity and acceleration of the center of mass were obtained by derivation of these polynomials. On the other hand, the data from the force platform were integrated in order to get the velocity increments.

## Validation

The validation has been done for two different phases of the jumps, namely the flying trajectory and the supported phase. For the first one, which corresponds to a parabolic path, the value of the second derivative ($y''$) of the respective describing equation was compared with the value ($g$) of the gravity acceleration. The percentage error [$E(g)$] was computed as:

$$e_i = (y'' - g)$$

$$e = \sum_{i=1}^{96} \sqrt{e_i^2} \; / \; 96$$

$$E(g) = 100 * e / g$$

$$E(g) = 21.61\%$$

For the supported phase the validation was obtained through the computation of the percentage errors relative to the respective time duration [$E(t) = 10.30\%$] and from the vertical velocity component [$E(Vy) = 23.94\%$].

## RESULTS

The performance (PL) for the long jump is computed by the equation which expresses the maximum horizontal distance travelled by the center of mass:

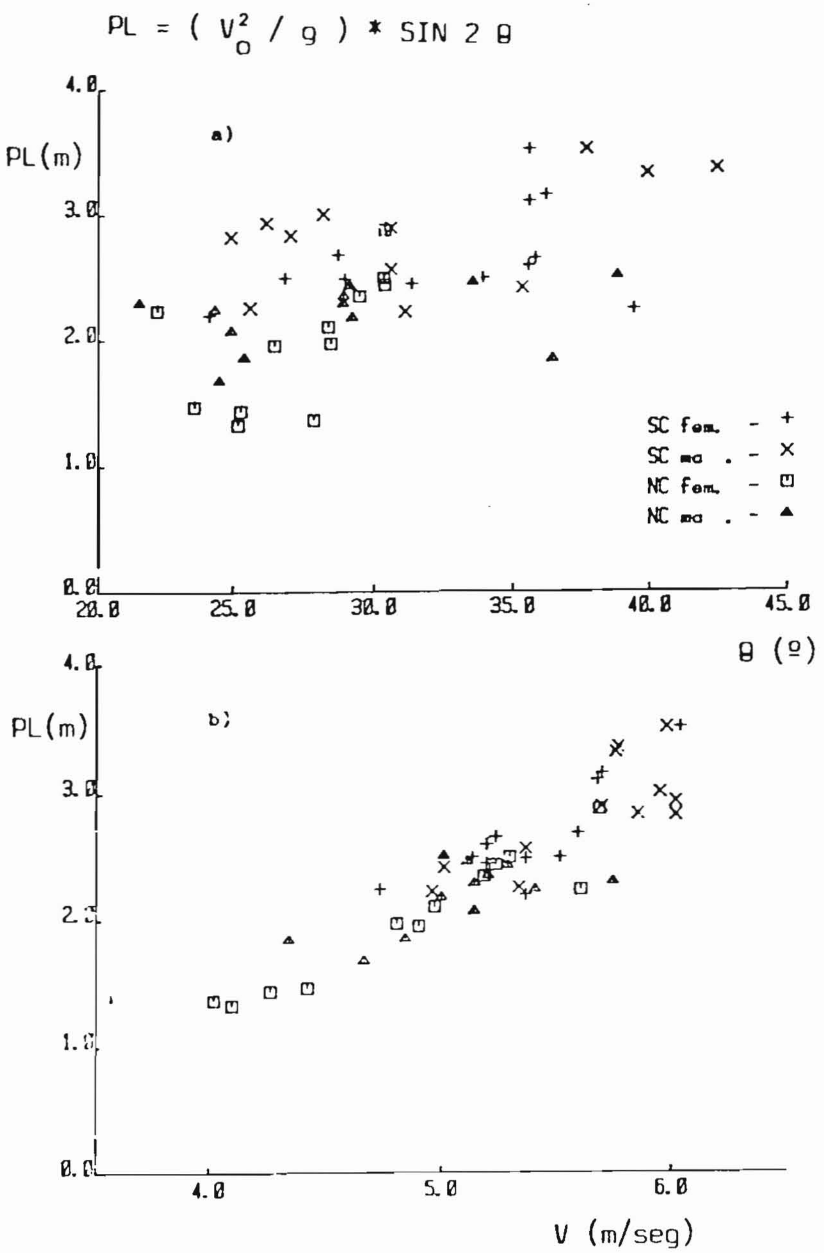

Fig. 1 Performance (PL) for the long jump as a function of the take-off parameters: angle (a) and velocity (b). Average values of PL: «SC» male (2.84 + 0.41) greater than «NC» male (2.18 + 0.26) «SC» female (2.67 + 0.38) greater than «NC» female (2.00 + 0.49)

The performance (PH) for the high jump is computed by the equation which expresses the maximum vertical distance travelled by the center of mass:

$$PH = (V^2_0 / 2 g) * SIN^2 \Theta$$

These two equations were applied to all the performances and the corresponding results are shown in Figures 1 and 2.

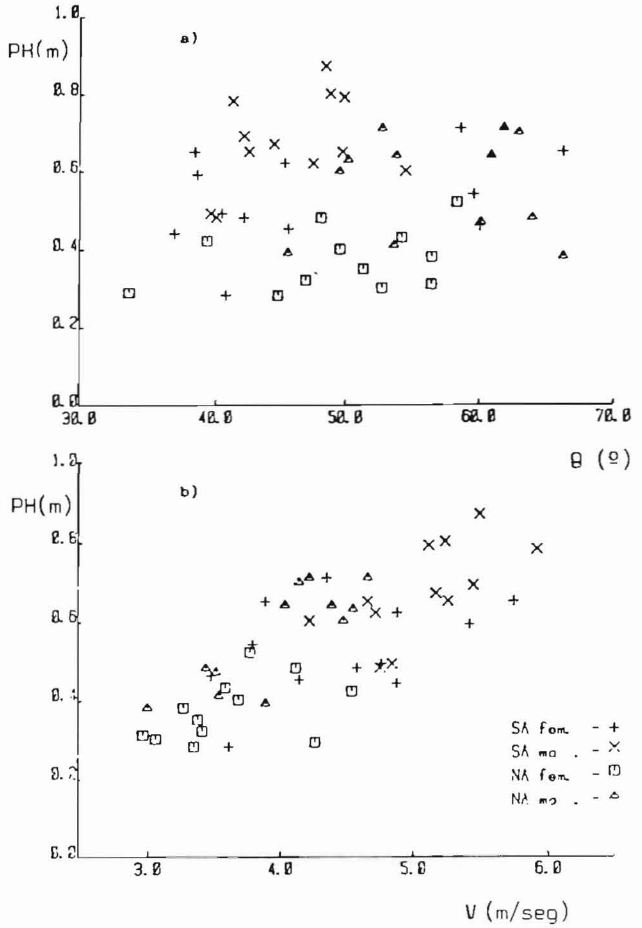

Fig. 2 Performance (PH) for the high jump as a function of the take-off parameters: angle (a) and velocity (b). Average values of PH: «SA» male (0.67 + 0.12) greater than «NA» male (0.56 + 0.12) «SA» female (0.53 + 0.12) greater than «NA» female (0.37 + 0.07)

## DISCUSSION AND CONCLUSIONS

The results presented above show clearly that experienced long jumpers have better performances in both circumstances thus suggesting that they acquired the mastery of the jumping pattern which they use even for the situation they had not been trained before.

These results also give support to the notion that all the performers have the capacity to integrate two types of mechanical behaviours: one corresponding to a rigid system and another to an articulated system. The first one, of a ballistical nature and essentially dependent on the energetical levels that can be mobilized by the performer, is illustrated by lower part of the previous figures. The second reveals the performer's capacity to reorient the velocity vector during the supported phase and is illustrated by the upper part of the same figures.

We suggest that the study of each one of the sports techniques should be complemented with the analysis of the motor patterns which integrate them. The sports technicians would surely put to good use all the information they could get on the mechanical characteristics of each one of such patterns, as well as on the way the coexisting rigid-articulated mechanical behaviours are integrated in them.

## REFERENCES

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