BIOMECHANIC EVALUATION OF RUNNING PERFORMANCES

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INTRODUCTION

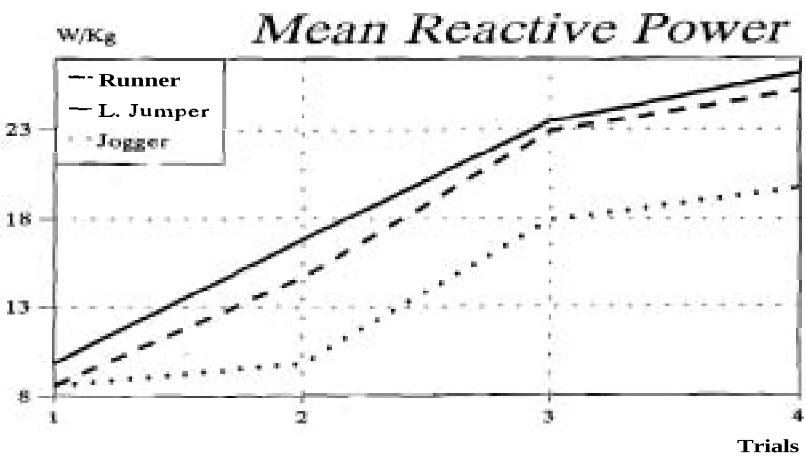
Running is the final result of a very complex coordination involving a lot of different anatomo-physiological contributions which are jointly provided by the neuro-muscular, the cardio-vascular, the respiratory and the metabolic systems. Given the obvious difficulty of performing a complete and detailed evaluation of all the variables associated with running, useful infonnation for practical applications is often obtained by analyzing the movement itself as an integrated descriptor of the whole process of coordination. However, even when only kinematic and dynamic aspects of running are taken into account, the large number of the available measures makes the study of correlation between variables very difficult to manage and to interpret. The aim of this study is to present a simple method for quantitative and synthetic description of the running performance and to show some preliminary results obtained through such a multivariable integration involving both kinematic and dynamic data.

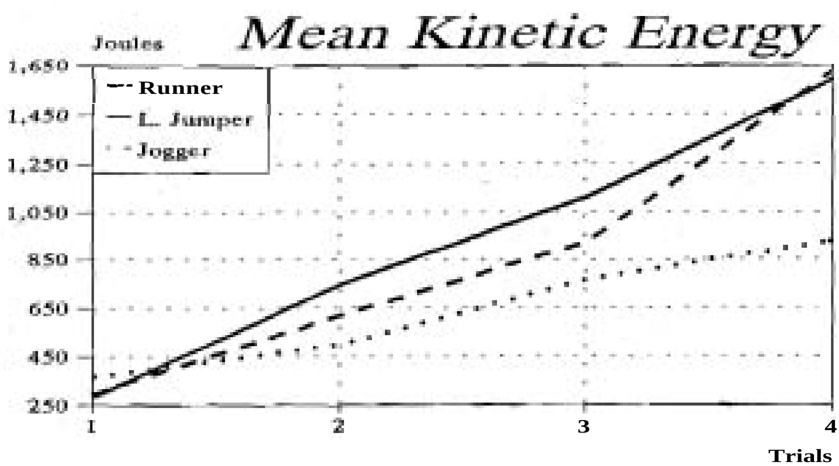
EQUIPMENT AND METHOD

The equipment adopted to measure the required kinematic data and ground reaction forces is essentially composed by two main units: the ELITE System (Ferrigno et al., 1989) which is an opto-electronic based 3-D motion analyzer, and a Kistler force plate. According with the ELITE hardware features, various small reflective hemispheres were preliminary placed on the runner's skin to mark suitable body repere points. In this application, only six passive markers were used to identify three anatomical landmarks (the anterior-superior iliac spine, the heel and the fifth metatarsal head) and the approximated position of the axis of flexion/extension of the hip, the knee and the ankle joints. The subject was then asked to run along a straight pathway about 30 m long at the four step cadences that are corresponding, by his own interpretation (and capability), to jogging, long and middle distance running and sprinting. After about two third's down the starting line, the force plate was located flush with the floor and centered with respect to the calibrated volume where the kinematic measures had to be taken. The acquired 3-D coordinates of the markers and the ground reaction forces were then processed in order to obtain the angular velocities and the reactive moments (Boccardi et al. 1981) at the lower limb joints, and the x and y velocity of the hip. Although the raw data were collected in 3-D, the analysis has been perfonned along the athlete's sagittal plane and during the stance-phase only in order to simplify the processing of the moments which have been computed without taking into account the anthropometric and inertial parameters of each athlete. The computed variables are:

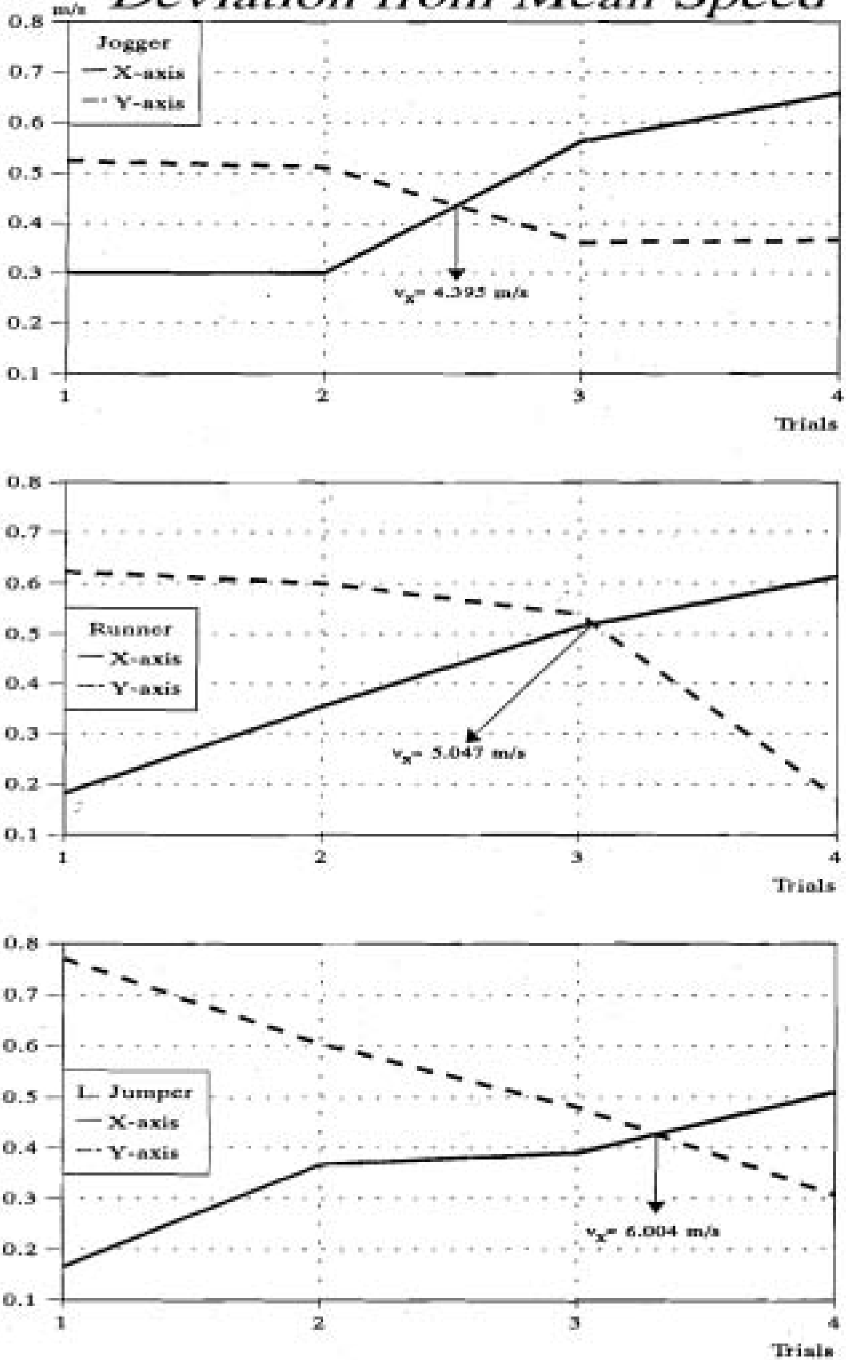
- the RMS reactive power (P,.), developed at the lower limb joints with respect to the body mass, computed as follows:

	Trials	Pr	Ekx	σ_x	σ_y
Jogger	1	8.580	366.155	0.300	0.525
	2	9.810	499.556	0.301	0.513
	3	17.927	766.660	0.563	0.362
	4	19.686	926.397	0.659	0.366
Runner	1	8.573	297.509	0.183	0.600
	2	14.665	619.570	0.355	0.513
	3	22.957	920.922	0.515	0.540
	4	25.236	1627.398	0.613	0.172
L. Jumper	1	9.835	282.205	0.166	0.771
	2	16.822	746.036	0.368	0.604
	3	23.502	1111.819	0.391	0.481
	4	26.219	1593.473	0.510	0.308





Deviation from Mean Speed



$$P_r = m^{-1} \, (\Sigma_i \, (P_i)^2 \,)^{1/2} \qquad i = hip, knee, ankle$$

$$P_i = (T^{-1} \int_{t1}^{t2} (M_{r,i} \, \omega_i)^2 \, dt)^{1/2}$$

where $T = t_2 - t_1$ is the stance-phase duration, $M_{r,i}$ Is the reactive moment around the i-fh joint , ω_i is the angular velocity around the *i-th* joint, *m* is the athlete's body mass.

- the kinetic energy E_{kx}, along the progression direction, computed as: $E_{kx} = 0 5 \, m \, v_x^2$ where v_x is the mean velocity along the progression direction of the hip joint marker which is supposed to represent the body center of miss.
- the standard deviations *a,* and σ_y from the mean values of the hip joint velocity along the advancing (v_x) and the vertical (v_y) directions.

RESULTS AND DISCUSSION

The results obtained by testing three different subjects are shown in the Table. The, three subjects had different running characteristics: one is just a jogger, the second is an amateur runner while the third is a professional long jumper. The two diagrams showing *P,* and E_{kx} could arouse, the following two considerations:

- in the middle range of running velocities (from point 2 to point 3) the three subjects provides P_r and E_{kx} curves having just a slight different trend. The amplitude shift among the three curves of power are roughly confirmed also in the curves referring to the energy;
- at slow velocities (from point 1 to point 2) the jogging trained subject provides the best performance given that his E_{kx}/P_r ratio is more advantageous with respect to the other two subjects. The less advantageous ratio is given by the long jumper;
- at fast speeds (from point 3 to point 4) E_{kx}/P_r ratio turns in favor of the long jumper while the jogger is following after the runner. A very large itnprovement of the above ratio is obtained, at the fastest velocity, by the runner.

However, the need of a good efficiency in the conversion of power into energy suggests the study of tlie velocity (or energy) deviations with respect to the mean vertical and horizontal values. The diagrams of σ_x and σ_y show that, for all the three aubjects, a characteristic progression speed occurs. In fact the intersection of the σ_x and σ_y curves, where the vertical dissipation of movenient equals the horizontal one, points out for each subject a typical advancing velocity which is changing as the runner ranking. Of course, this finding is worth being further investigated but the regularity with which it arises is quite surprising and, if confirmed by other results, it may represent a synthetic performance index to monitor the running capabilities of a subject.

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