EVALUATION OF THE LOWER LIMBS MOTOR STRATEGIES DURING VERTICAL JUMPING

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INTRODUCTION

Vertical jump is a test widely adopted in sport practice to obtain indications on some motor characteristics of the athletes. Biomechanists are interested in different aspects of this movement. By considering the motor coordination, Hay et al. (1980) identified that the temporal and spatial coordination patterns between the angular movements of the joints determine shape and size of the vertical net impulse, thus the height of the jump. The muscular strategies, studied through articular torques and powers and EMG signals, have been deeply analysed by Gregoire et al. (1984). Bobbert and van Ingen Schenau (1988). Pandy and Zajac (1991) integrated the kinetic data with a mathematical model of optimal control to estimate the muscles' power. All these authors agree in identifying a proximal-to-distal sequence of muscles' activation, but Pandy and Zajac results are in opposition with the notion of Bobbert and van Inge Schenau that energy flows distally and on the interpretation of the role of some monoarticular muscles of the lower limb (Gluteus Maximum and Vasti). Anyway all the studies point out the different contribution of the joint muscles and the influence of motor coordination on the performance. Relatively few authors aimed the purpose of a practical application of the vertical jump for training evaluation (Bosco and Komi, 1982, Oddson, 1989).

The aim of this paper is the study of the vertical jump by means of the variables related to the mechanical contribution (net torqes and powers) of the muscular groups acting on the three main joints of the lower limb. This was developed in order to identify a quick and reliable procedure useful to evaluate the motor patterns and then to help the trainer in setting up optimal training and recovery procedures.

METHOD

Subjects of the study were 9 professional football players (Body Mass=71 [Kg] S.D.=7.4, age=17.6 [years] S.D.=0.5, height=1.79 [m] S.D.=0.07). The players, after warm up, performed series of 1/2 squat vertical jumps using either the thrust of both the legs, or the thrust of only the left leg or the right one. All the jumps were performed with the movement of the upper limbs. The data of three trials per condition were recorded.

The coordinates of five anatomical landmarks of the lower limb and the ground reaction force, measured with a Kistler force plate, were detected simultaneously by the ELITE System (Ferrigno and Pedotti. 1985) with a sampling frequency of 100 Hz. A specially designed software was implemented to compute the performance index (height of the jump) through the integration of the vertical component of the ground reaction force, the net joints' moments and the corresponding powers.

RESULTS

The performance index (average=539 mm. S.D.=45) of the jumps performed with the thrust of both the legs, confirms the high athletic level of the players. When the players jump with the thrust of one leg the performance index decreases (average=366 mm., S.D.=44) without evidencing significative differences on the average between the left and right side. Moments an powers time courses of vertical jump using the two legs confirm the peak timing reported by Bobbert and van Ingen Schenau, with the hip reaching the maximum firstly followed by knee and ankle maxima respectively. The mean values and standard deviations computed on the data of the athletes' group are reported in table I. The data show that the maximal moments exerted by the joints muscles when only one limb is acting, are significatively greater than the correspondent values computed on the same leg during the action of both the limbs. This difference almost disappears when the powers are considered. This implies that the two modalities of jumping allow to describe the motor action of the lower limbs under different conditions of angular joint velocity. and it means under different velocity of contraction of the muscular groups which is lower when jumping using one leg. The comparison of moments and powers of table I with the data reported by Bobbert and van Ingen Schenau for a two legs vertical jump, performed with countermovement, enlight a little decreasing of hip and ankle moments expressed by our population, while the decrease shown at the knee is more appreciable (almost 55 %). The same has been recognised by considering the powers: in this case, the decrease of the average peak at the knee is very high (almost 120 %). The discrepancy may be explained by the difference between the kinds of vertical jump and the population: in that case, taller and heavier volleyball players were tested. It is then hopeful to set up a common protocol useful to allow the comparison of data measured by different groups of research.

		VJ two legs	VJ right leg	VJ left leg
	HIP	147.1 (15.8)	218.6 (27.8)	212.2 (30.4)
MOMENTS	KNEE	109.7 (18.9)	166.8 (32.3)	165.9 (23.6)
[N*m]	ANKLE	137.7 (16.6)	199.9 (29.2)	218.1 (25.7)
	HIP	528.9 (50.8)	568.1 (106.4)	479.7 (135.1)
POWERS	KNEE	545.6 (162.2)	497.7 (60.6)	472.3 (119.0)
[watts]	ANKLE	1051.7 (207.5)	1096.6 (243.7)	1199.3 (237.2)

Table I Mean value and standard deviation of moments and powers measured on the subjects when executing the different vertical jumps.

The analysis of the relationships between the height of the jump and the data of table I, points out that there is a positive correlation with the peak moments, but the R coefficients range between values too low (0.249-0.667) in order to allow any serious prediction on the status of the joint

muscular groups through the performance index. Similar considerations may be drawn through after the analysis of the R coefficients computed between powers and height of the jump.
The-data reported in table II confirm that, even if vertical jump is a simple exercise easy to perform correctly by people with high motor skills, this test allows to identify mechanical and motor asymmetries between the same muscular groups of the two legs of an athlete. Athlete A reached significatively highest performance index when jumping on the right leg (+70 mm). The asymmetry was related with higher hip and knee moments. The same has been verified for the powers, but the amplitude of the power measured on the left hip is higher than on the right one, underlying the attempt to compensate the contribution of the less powerful limb, by means of a change of the motor strategies. It is important to note that athlete A, during the experiment, was afflicted by talalgia of the left foot, who implies a reduction of the tension expressed by the Triceps Surae, with a consequent reduction of the plantar flexion action and a modification of the Gastro Medialis and Lateralis intervention at the knee.

		ATHLETE A		ATHLETE B	
		VJ right leg	VJ left leg	VI right leg	VJ left leg
	HIP	200.1 (42.5)	179.7 (9.1)	218.5 (13.5)	241.6 (5.9)
MOMENTS	KNEE	146-6 (5.7)	120.2 (2.4)	189.9 (13.3)	227.2 (15.6)
[N*m]	ANKLE	180.4 (8.7)	145.9 (1.7)	237.3 (10.5)	229.3 (5.4)
	HIP	378.2 (21.8)	503.7 (43.2)	504.1 (16.3)	605.6 (33.1)
POWERS	KNEE	493.5 (50.0)	372.4 (86.9)	467.5 (12.5)	546.6 (11.5)
[watts]	ANKLE	1191.2 (190.2)	776.8 (75.7)	1406.7 (26.5)	1214.8 (9.2)

Table II Mean value and standard deviation of moments and powers measured on two subjects when executing the vertical jumps on one leg. Athlete A shows a significative higher performance index when jumping on the right leg (70 mm., $p>0.001$) as athlete B when jumping on the left (61 mm.).

Athlete B, an healthy subject with the dominance of the left leg (+61 mm.), obtains these results by exerting higher moments at he hip and, more evidently, at the knee joint while the moments at the ankle joint are similar. The same is confirmed by the powers. In terms of training program the results suggest exercises aimed to increase the strength of the muscles providing the extension of the upper joints of the tight leg and this indication could be very important to prevent future injuries depending on the muscular unbalance.

CONCLUSIONS

The availability of an equipment for on line data recording of kinematic variables and ground reaction forces, joined with proper computing program encourages to use the mechanical moments and powers of the lower limbs, to monitor the athletes by a biomechanical point of view. The use of vertical jump, inside a well defined protocol of execution, seems to be an useful tool to identify the motor status of the most important muscular groups of the lower limb and then to identify specific problems of the athletes due to asymmetries depending on proper characteristics or defective recovery after injuries.

The described test requires less than an hour from the trial performing to the results presentation. The routinary use of such a test within the training programs of the athletes seems to be helpful in the definition and monitoring of training procedures.

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ACKNOWLWDGEMENT

This study has been supported by the Italian Research Council (CNR) CN 88.018 15.04.