MONITORING OF SPRINTERS' MOTOR COORDINATION THROUGH VERTICAL JUMP EXERCISES

R. Rodano[1] and R. Squadrone[2]

[1]Dipartimento di Bioingegneria
Politecnico di Milano
Milano, Italy

[2]Centro di Bioingegneria
Fondazione Pro Juventute
Politecnico di Milano
Milano, Italy.

INTRODUCTION

Some changes in contractile capacity, and hence in the production of force, are the inevitable outcome of a muscle injury. Once an injury of an athlete is rehabilitated, isokinetic dynamometers are usually employed to measure the force and power of agonist and antagonist muscle groups at different contraction speeds, in order to set up the optimal training program.

However, isokinetic dynamometers do not permit a complete evaluation of motor coordination. Due to the imposed movement constraints they cannot show the subject's ability to integrate muscle contractions into an efficient quick movement. It is thus important to determine not only the static anatomical-pathological aspects of such injuries, but also their dynamic effects on motor coordination.

Vertical jumping is a complex ballistic movement, involving various energy release, storage, and power flow mechanisms, in which the musculature of the lower limbs operate collectively to produce patterned movements. Hence vertical jumping exercises have several advantages compared to dynamometers. Unfortunately, despite the large number of studies conducted by researchers on biomechanical parameters involving these exercises, coaches usually take into account just the athlete's vertical displacement or other ground reaction force (GRF) derived parameters (e.g. maximum vertical force, peak power).

Even if these indices are important common evaluation methodologies, they seem inadequate in monitoring the motor coordination status as a function of training and rehabilitation programs. This study describes the motor strategies adopted by a homogeneous group of athletes (sprinters), while executing vertical jump exercises, by means of the mechanical ouput of the lower limbs joints (moments and powers). This study is the first step of a long term program aimed to point out that the modifications of the motor strategies due to a training program are individual modifications due to possible injuries.

METHODOLOGY

Nine male track and field sprinters of national class (range of their best performance on 100 m from 10.4 s to 10.8 s) were the subjects of this study. Average and standard deviation for age, height and body mass were as follows: 23.0 ± 3.4 years, 175.3 ± 8.6 cm, and 74.9 ± 18.3 kg.

The test sessions were conducted during the second cycle of the preparatory training season in autumn. At the time of the experiments all the subjects were free of lower limb dysfunction and injury. They trained regularly 2-3 hours a day, 5-7 times a week and training regimes consisted mainly of sprint training, sprint co-ordination, strength training, and various kind of jumps, hops and bounds.

After 20 minutes of standard warm up, the athletes were asked to jump as high as possible while keeping the hands on their waist to minimize extraneous motion in the upper body. They performed jumps either with the thrust of both legs or the thrust of one leg. For the one-legged jumps an additional instruction was to keep the non-pushing leg inactive under the body. All subjects had previous experience in this kind of test and choose spontaneously to perform a preparatory countermovement. Each trial was followed by two minute rest period. Data of four trials per condition were recorded.

The 3-D coordinates of ten anatomical landmarks (five per leg) were detected by the optoelectronic ELITE System (Ferrigno and Pedotti, 1985) with a sampling frequency of 100 Hz. Simultaneously the GRF signals were measured by a Kistler force plate and acquired with a sampling frequency of 1000 Hz.

Internal joint centers of both legs were estimated from anthropometric and kinematic data using a special software package (Pedotti and Frigo, 1992). Moments and powers of the leg thrusting on the force plate (for two-legged jumps only one foot at time was on the force plate) were estimated by using the same software package. The jumping height (displacement of the center of gravity after the toe off) was computed by integrating the vertical component of GRF, and by applying the equations of projectile motion.

RESULTS AND DISCUSSION

The mean jumping height values were 48.70 cm. (sd 5.64) and 25.16 (sd 3.63) respectively for the two-legged and one-legged jumps. Jumping height in one-legged efforts were 51.65% of the performance with both legs. This value is rather smaller than the 58.6% reported by Van Soest (1985).

The kinetic variables concerning the performance of one- and two-legged jumps for the whole group are presented in Table 1.

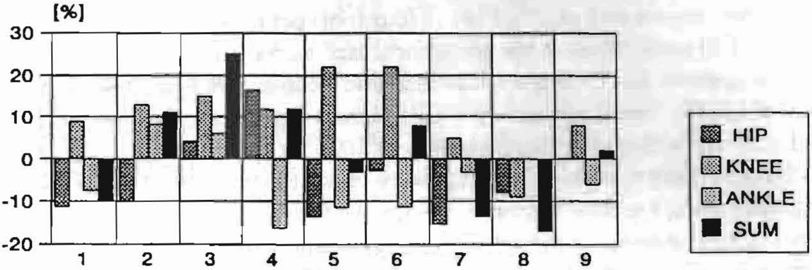
Table 1. Mean values and standard deviations of the maximum moments and powers, measured during one-legged and two-legged vertical jumps.

	Moments (Nm)				Powers (Watts)			
	1 Leg		2 Legs		1 Leg		2 Legs	
	Mean	sd	Mean	sd	Mean	sd	Mean	sd
Hip	212.6	44.6	153.2	31.2	372.0	108.7	506.5	145.5
Knee	268.2	37.5	184.1	29.1	858.6	205.4	912.6	215.0
Ankle	163.1	25.1	117.0	15.9	987.1	167.5	792.0	130.1

Notice that the jump modalities are almost the same, thus it is meaningful to compare the results of this study with data reported by Van Soest. By considering powers for two-legged jumps, it can be seen that although absolute values are considerably different, once normalized to body weight and height, they became very similar at the hip and knee joints. Significant differences, however, exist at the ankle joint. The difference was more pronounced when one-legged jumps were considered where differences also appear at the hip and knee joints.

When the moments were analyzed, our normalized values were similar for two-legged jumps (hip: 1.22 vs 1.27, knee: 1.12 vs 1.11, ankle: 0.89 vs 0.95) and significantly different for one-legged jumps (hip: 1.69 vs 1.38, knee: 1.34 vs 1.22, ankle: 1.30 vs 1.58). This and other comparisons with the data from previous studies (Rodano and Bulgheroni, 1992) is not easy due to the different experimental and analysis procedures and groups of subjects.

The powers exerted when only one leg was acting were significatively smaller at the hip ($p<0.01$), slightly smaller at the knee (non-significant), and significatively greater at the ankle ($p<0.01$) than the corresponding values computed during bilateral efforts.



	1	2	3	4	5	6	7	8	9
HIP	-11,3	-10	4,2	16,5	-13,6	-2,8	-15,4	-8	0
KNEE	8,9	13	15	11,8	22	22	4,9	-9	8,1
ANKLE	-7,4	8,2	6	-16,3	-11,5	-11,3	-3,1	0	-6
SUM	-9,8	11,2	25,2	12	-3,1	7,9	-13,6	-17	2,1

+ = R > L - = R < L

Figure 1. Asymmetry indices computed for each athlete on the maximum joint powers during two-legged vertical jumps. Positive values point out the dominance of the right leg, negative values the dominance of the left.

According to the results of Rodano and Bulgheroni (1992), the majority of subjects show significant asymmetries when executing vertical jumps alternatively with the right and left leg. Surprisingly, by examining the scores of bilateral jumps, a great number of asymmetries in moment and power amplitude and time sequence distribution at main lower limb joints were found. Figure 1 depicts the results concerning bilateral differences in power peak amplitude. To our knowledge, no data are currently available in the literature on functional asymmetries during bilateral efforts in high speed explosive movements and it would appear that vertical jump is not so "symmetric" as previously though.

CONCLUSIONS

The large inter-subject variability in power patterns and peak amplitude demonstrate how the athletes use their major muscle groups differently to perform a very similar gross movement pattern. Even if casual relationships and a quantitative explanation of the kinetic patterns at each joint are impossible, due to the intrinsic nature of joint net moments and powers, the method described allows one to discern the presence of faults and overloads in jumping technique.

The asymmetries in kinetic variables underline individual differences in lower limb strength, speed, and motor coordination in both unilateral and bilateral efforts.

The validity and usefulness of this measurement system, as any other designed to help athletes perform exercises at their best potential, is always strictly related to the availability of normative data from professional athletes involved in different sport activities. This problem could be overcome by employing this procedure as a screening test. Each athlete could be subjected to the test when the coach considers that he is in good shape. Thus it would be possible to maintain a pre-injury or baseline profile of the athlete, thus providing an objective and quantitative measurement of the modifications dependent on training or recovery programs. In order to exchange information between research groups, it will be fundamental to spend time and energy to set up common test procedures and basic data elaborations.

REFERENCES

Ferrigno G. and Pedotti A. (1985). ELITE a digital dedicated hardware for movement analysis via real time TV signal processing. IEEE Trans. Biomed 32:943-950.

Pedotti A. and Frigo C. (1992). Quantitative analysis of locomotion for basic research and clinical applications. Supp. to Functional Neurology 7(4):47-56.

Van Soest A. J., Roebroeck M. E., Bobbert M. F., Huijing P. A., van Ingen Schenau, G. (1985). A comparison of one-legged and two-legged countermovement jumps. Med Sci Sport Exer 17(6):635-639.

Rodano R. and Bulgheroni M. (1992). Evaluation of the lower limbs motor strategies during vertical jumping. In Proceedings of ISBS. R. Rodano, G. Ferrigno, G. C. Santambrogio (eds.). pp. 124-127. Milano, Italy: EDI-ERMES.