LOWER LIMB KINETIC VARIABILITY IN VERTICAL JUMPING

R. Rodano[1,2], R. Squadrone[2], M. Rabuffetti[2], and A. Mingrino[2]

[1]Dipartimento di Bioingegneria, Politecnico di Milano, Milan, Italy.
[2]Centro di Bioingegneria, Fondazione Pro Juventute - Politecnico di Milano Milan, Italy.

Introduction

For more than 50 years vertical jumping exercises have been widely used in sport practice as a measure of power not only to predict athletic ability but also to obtain indications on same neuro-muscular and motor characteristics of the athletes. The most interesting work in this area has been done by a research group at the Free University of Amsterdam. The studies of these authors (van Soest et al., 1985; Bobbert & van Ingen Schenau, 1988) evidenced very elegantly that kinetic analysis provides potentially more diagnostic information about motor condition than the usual approach based only on ground reaction force derived indices.

However, what the majority of previous studies on human movement based on the moment and power model did evidence was the extremely large intrasubject variability of the joint kinetic variables (Winter, 1984). In the evaluation of joint kinetic measurements, errors can came from many sources: 1) subject variability depending on human biovariance; 2) characteristics of the instrumentation employed to collect kinematic and kinetic data; 3) accuracy of the model, marker positioning, and skin artefacts related to the inverse dynamical approach and the use of optoelectronic systems.

So far, no attempts have been made to gain more insight into the variability inherent in moment and power selected measurements in vertical jumping exercises. To the best of our knowledge, in fact, all the studies employed one or more homogeneous subject groups and presented data describing the average performance of the groups. Furthermore, frequently, when mean values of the kinetic parameters for a group were calculated, only the highest jump of each subject was selected for the calculation (Bobbert & van Ingen Schenau, 1988).

The present experiments were devised to gain more insight into the variability of the peak values of moments and powers, measured at hip, knee, and ankle joint, in order to determine the appropriate number of trials necessary to obtain a stable mean for these parameters.

Methods

Eight recreational athletes (body mass: 64.4 ± 10.9 kg; height: 174.3 ± 7.7 cm; age: 26.6 ± 6.2 yr.) were the subjects of this study. After a period of time in which the athletes were allowed to warm-up and became familiar with the experimental setting, each subject performed 5 series of 5 double-legged countermovement vertical jumps without the arm swing. Between the jumps and the series, the subjects rested 1 min and 4 min respectively.

Kinematic data, concerning the spatial position of ten anatomical landmarks (five per each leg), were recorded by means of an optoelectronic system (ELITE) with a sampling rate of 100 **Hz.** Simultaneously ground reaction forces were measured with a Kistler force platform at the sampling rate of 1000 **Hz.** The internal joint centers, such as the corresponding moments and powers, were estimated by using a special software (SAFLO) which inputs were anthropometric, kinematic and kinetic data.

For each subject the kinetic variables were analyzed computing their coefficient of variation (CV) and applying the sequential estimation procedure. The CV used in this study is those for discrete data and was computed as the percentage ratio between the standard deviation and the mean of the 25 trials. In the sequential estimation procedure (Hamill & McNiven, 1990) a value is generated for the cumulative mean adding one trial at time. The criterion to obtain a stable mean for each variable was met when the cumulative mean fell within the 25-trial mean ± 0.35 the standard deviation of the 25 trials.

Results and discussion

In table 1, mean peak joint moment and power values for the whole group are presented. Most of the subjects exhibited the highest moments at the knee and the lowest at the ankle while, considering powers, the highest and the lowest values were found respectively at the ankle and at the hip joint.

As shown in table 2. comparing the variability of each single joint. the mean CV values were higher at the hip and lower at ankle for both moments and powers, while the knee joint showed intermediate values. In other words. the data showed a trend of decreasing variability moving proximally to distally. Comparing moment and power values, CV of powers were significantly greater ($p<0.05$) than those of moments.

Table I. Mean values and standard deviations of peak moments and powers for the whole group.

	MOMENTS [N·m]		**POWERS** [Watts]	
	Mean	SD	Mean	SD
HIP	102.4	36.3	310.5	109.8
KNEE	116.7	33.7	509.4	200.3
ANKLE	89.4	18.2	622.1	149.7

Table 2. Mean values and standard deviations of coefficient of variation of peak moment and power values.

	MOMENTS		POWERS	
	Mean	SD	Mean	SD
HIP	12.6	4.1	15.2	4.2
KNEE	6.8	3.2	11.5	3.6
ANKLE	5.9	1.9	8.7	2.6

Figure 1 display a graphical example of the sequential estimation technique for a subject of this study. As it can be seen, the knee and ankle peak power get stable after 8 trials, while hip peak power takes 10 trials to reach stability.

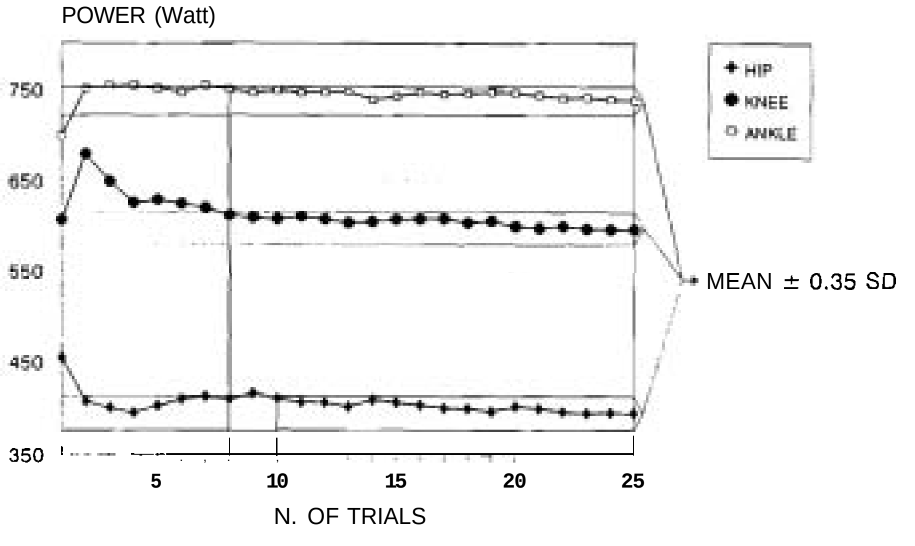

Figure 1. Graphical example of the sequential estimation procedure for a subject of this study.

In table 3, the results of the sequential estimation technique are illustrated. The hip moments appear to be the most critical variable, as they required a mean number of 13 trials to reach a stable mean. Since the mean number of trials for each variable was greater than 7 and less than 13, a mean of at least 13 trials may be considered necessary to produce a stable mean for all the kinetic variables considered. When hip moments were excluded from analysis, the mean number of trials ranged from 7 to 10. In this case, a 10-trial mean number may be considered the optimum number of trials necessary to reach a stable mean.

Table 3. Mean number of trials necessary to reach a stable mean for each variable.

	MOMENTS Mean	MOMENTS SD	POWERS Mean	POWERS SD
HIP	12.9	3.2	8.8	2.8
KNEE	8.3	4.6	10.3	4.3
ANKLE	10	5.1	6.8	4

Conclusions

The variability analysis showed the existence of a large intersubject and intrasubject variability in peak power and moments during countermovement vertical jumping exercises. Furthermore, the size of variability was joint and subject dependent. These findings suggest the need to adopt multiple trial protocols to assess the athlete characteristics.

The stability analysis revealed that at least a 13-trial protocol is necessary to establish a true measure for all the selected parameters. Excluding hip moment values, a 10-trial protocol may be considered sufficient.

Further works aimed to assess the intraday and interday variability, and monitor the athlete characteristics over the season as well, should take into account the results of this study.

References

Bobbert, M. F., & van Ingen Schenau, G.J. (1988). Coordination in vertical jumping. Journal of Biomechanics, 3,249-262.

Hamill, J., McNiven S.L. (1990). Reliability of selected ground reaction force parameters during walking. Human Movement Science, 9, 117-131.

van Soest, A.J., Roebroeck, M.E., Bobbert, M.F., Huijing, P.A., & van Ingen Schenau, G.J. (1985). A comparison of one-legged and two-legged countermovement jumps. Medicine and Science in Sport and Exercise, **17,** 635-639.

Winter, D.A. (1984). Kinematic and kinetic patterns in human gait: Variability and compensating effects. Human Movement Science, **3**, 51-76.