DYNAMICAL FACTORS RELATED TO VERTICAL JUMP PERFORMANCE

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INTRODUCTION

In most of sport exercises, the displacement of body center of mass is an important factor to determinate performance. And higher the velocity at takeoff phase, higher the height achieved by the body center of mass. Jumps are influenced by the combination of temporal and kinetical factors of different joints moments during this task (AMADIO, 1989). Moreover, also the counter movement may influence high jump performance (HARMAN et al., 1990). Although the concepts and mathematical definitions of center of mass and ground reaction force are not the same, their vertical components have a similar behavior since both are formed from vertical accelerations of each part of the body. To measure the effectiveness of training into increasing the height in vertical jump relays information to both coach and athlete in manner to adapt the training.

The purpose of this study is to analyze temporal and frequency factors of ground reaction force and the effect of limitation of upper limbs swing and hip flexion during vertical jump. And a comparative analisys is used to determinate different behaviors from dynamical factors for a movement task easily seen in distinct sport techniques.

METHODS AND EQUIPMENT

All the exercises were performed on a strain gauges force platform. The vertical component of the ground reaction force had been sampled at 800 Hz frequency and after the determination of its frequency components and amplitude signals by the use of Fast Fourier Transform, the raw signals were low-pass filtered at 100 Hz. A video camera was used to register the lateral plane of all jumps and was exerted to externally control the set of jumps, by registering the subjects performance. The volunteer subjects for this study was two healthy male, 26 and 25 years old, 76.4±0.5 and 75.2±0.5 kg weight, 184.0±0.5 and 172.0±0.5 cm tall, here named subject A and B respectively. Four different types of vertical jumps were performed (set of 5 trials) and analyzed in this study: 1) standard vertical jump; 2) jump without the elevation of upper limbs; 3) jump without the flexion of hip; and 4) jump without both the elevation of upper limbs and flexion of hip. All that jumps were preceded by counter movement. Before the measurement, the subjects have trained each type until they consider that they have achieved the pattern of movement. The hip flexion was controlled through the video, and it was discarded any trial that produced an angle bigger than 10° with a vertical reference put on the scene.

Before the estimation of mean values related to the vertical ground reaction force, all the results were normalized at a same temporal basis.

RESULTS AND DISCUSSION

The vertical ground reaction force of four different types of jumping used in this study are illustrated in figure 1. Those curves represent the ensemble average of the set of trials for each type of jumping under a normalized time to ensure that all curves start and end at a same position. The variability of each set range from 8 to 17 %, according to the coefficient of variability. The movement of upper limbs and trunk improve the counter movement in vertical jumping, providing time to the motor system reaches a higher level of energy to performance. And the enhancement of the coordination of partial impulses improves the total impulse of the body.

The patterns of ground reaction force for subject A and B and quite different. While subject A rose the first positive peak in the vertical component of ground reaction force (Fz_1) in non-restarted conditions, subject B rose the second positive peak in the vertical component of ground reaction force (Fz_2). As subject A produces greater negative impulses, it was necessary to increase the Fz_1 to equalize it; in contrast, during type 4, the subject B almost eliminated this first peak (figure 1). Another difference in normal performance is the existence of a positive impulse during the counter movement of subject B.

Comparing the performance between type 1 and 2 (table 1), is clear a maintenance of a similar value of Fz_1 in contrast to the reduction of Fz_2. Types 1 and 3 showed the highest values of Fz_2 (when upper limbs do not have restriction to move). Although ground reaction force results from the coordination of net impulses, the fact that under a restriction of acceleration of the upper limbs (type 2) and the reduction of Fz_2 indicate that upper limbs acceleration are related to rise Fz_2 (it is important to remember that even though when those segments are restricted to move, still it is not possible to eliminate the contribution of their moments of inertia).

a　　　　　　　　　　　　　　　　　　　b

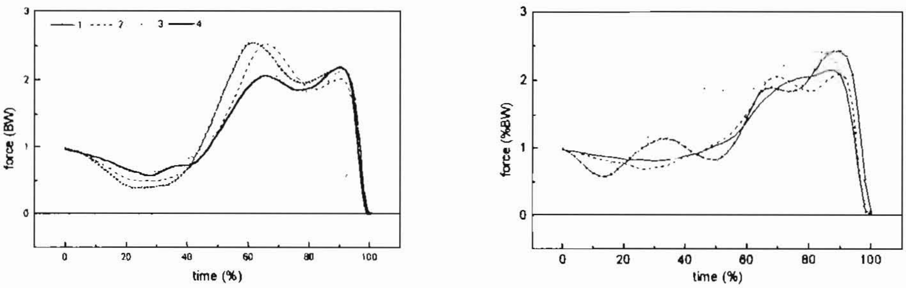

FIGURE 1. Ensemble average of vertical component of ground reaction force in relation to body mass (%BW) for the types of jump analyzed: 1) standard vertical jump; 2) jump without the elevation of upper limbs; 3) jump without the flexion of hip; and 4) jump without both the elevation of upper limbs and flexion of hip.

In subject B, who has higher values in Fz_2, it was observed that only about 20% was the rate negative/positive impulses for type 3 and 4, but in the other hand, above 30% was the rate for type 1 and 2. To keep the balance when the knees are bent during counter movement, two strategies are used: ankle plantar flexion and hip flexion. Thus, decreasing the range of movement of hip will probably affect the knee flexion, reducing the negative impulse. Therefore, these values indicate that trunk mobility may be more influent in the negative phase.

Our results indicate that the first positive peak is probably exerted by hip flexion (figure 1b), because when the trunk acceleration was reduced by limiting the hip flexion, the curve of vertical ground reaction force was smoothed and its positive peaks were similar (table 1).

The frequency analysis only presented some different results in subject A. The spectral distribution changed due to the type of jumping, but it was not conclusive that certain parts of spectrum is particular related to the acceleration of a specific part of the body. Only one difference was identified between A and B: amplitudes between 3 and 7 Hz were higher in subject A.

The following table presents some dynamical variables related to jump performance.

TABLE 1. Results of parameters related to vertical ground reaction force; h is the maximum vertical displacement; Δt_{12} is the period between Fz_1 and Fz_2; I_n is the positive impulse and I_p is the negative impulse; I_n/I_p is the rate between negative and positive impulses. T is the total time duration of the jump.

subject A

	1	*2*	*3*	*4*
h (cm)	49.4±0.2	40.8±0.9	44.2±0.2	37.0±0.9
Fz_1 (%BW)	2.54±0.07	2.53±0.04	2.10±0.04	2.06±0.19
Fz_2 (%BW)	2.17±0.07	2.02±0.04	2.13±0.07	2.19±0.07
Δt_{12} (%T)	29.2±0.5	24.7±0.5	24.6±0.5	24.9±0.5
I_n ($BW.s^{-1}$)	16.7±0.5	13.8±1.1	10.2±0.2	10.6±1.8
I_p ($BW.s^{-1}$)	38.9±1.3	33.4±0.9	32.8±1.9	32.1±3.3
I_n/I_p	0.43±0.02	0.41±0.06	0.31±0.01	0.33±0.02

subject B

	1	*2*	*3*	*4*
h (cm)	31.8±0.8	30.6±0.2	30.6±0.2	27.0±0.4
Fz_1 (%BW)	2.03±0.07	2.06±0.04	2.26±0.04	n
Fz_2 (%BW)	2.43±0.07	2.10±0.04	2.43±0.07	2.15±0.07
Δt_{12} (%T)	23.0±0.5	20.5±0.5	14.0±0.5	n
I_n ($BW.s^{-1}$)	7.8±0.5	11.3±1.1	5.0±0.2	5.9±1.8
I_p ($BW.s^{-1}$)	26.9±1.3	21.9±0.9	27.4±1.9	27.6±3.3
I_n/I_p	0.29±0.02	0.52±0.06	0.18±0.01	0.21±0.02

CONCLUSION

Despite different jumping exercises, restrictions to joints mobility changes the maximum vertical ground reaction force and it is clear that is not possible to exclude their influence in total body moment of inertia. DOWLING & VAMOS (1993) point that is unknown what is the function of arms swing to increase the height. Our results indicate, by the coordination of partial impulses, that arms swing are related to transfers momentum near to the takeoff. It was observed that the rate between negative and positive impulses changes due to the constraints that are imposed to the movement. It is necessary to improve the methodologies to measure eccentric/concentric phases as a manner to identify and to correlate to partial impulses during a movement. The effect of constraints and counter movement on vertical jump relay information to understand the reason to use different kinetic chains to develop a skill, because the motor system have to adequate different strategies to keep a better performance.

REFERENCES

AMADIO, A.C. (1989) Fundamentos da biomecânica do esporte: considerações sobre a análise cinética e aspectos neuro-musculares do movimento. São Paulo, 119p. Tese (Livre Docência) - Escola de Educação Física, Universidade de São Paulo.

DOWLING J.J.; VAMOS L. (1993) Identification of kinetic and temporal factors related to vertical jump performance. Journal of Applied Biomechanics 9: 95-110.

HARMAN, E. A.; ROSENSTEIN, M.T.; FRYKMAN, P.N.; ROSENSTEIN, R.M. (1990): The effects of arms and counter movement on vertical jumping. Medicine and Science in Sports and Exercise, 22(6): 825-833.