VARIATION IN SEGMENTAL KINETIC ENERGY DURING EXECUTION OF GIANT SWINGS ON THE HORIZONTAL BAR AT DIFFERENT SPEEDS

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INTRODUCTION: In the giant swing on the horizontal bar, at the lower part of the rotation the kinetic energy obtained by the body is not enough to return to the initial position, i.e., above the bar, because of mechanical energy losses due to friction and air resistance. Furthermore, many acrobatic movements require greater swinging speed. To compensate for the loss of mechanical energy, the gymnast must move according to the rules of the International Gymnastics Federation. For coaches the beat swing, which begins just after the vertical under the bar, is fundamental. Thus, the mechanical work of this movement has been partially described (Okamoto et al., 1988), and variations of the trunk and leg kinetic moments were studied, particularly in release-regrasp skills (Gervais and Tally, 1993), but, without explaining the augmentation of kinetic energy. The aim of this study was to characterize the variation of segmental and total kinetic energy and to specify how the augmentation of kinetic energy that made possible the performance occurred.

METHODS AND PROCEDURES: Three expert gymnasts performed three backward giant swings on the horizontal bar under three experimental conditions characterized by the following speeds: slow, natural and fast rotation. An S-VHS video camera, placed on the axis of the horizontal bar, was used to record movements in the sagittal plane. Markers were fixed on several body segments according to anthropometric studies (Winter, 1990; Zatsiorsky et al., 1990). The body was represented by three segments (superior members, trunk and head, inferior members).The S-VHS video tape allowed us to obtain 50 frames per second. Frames were analyzed using original software (Dyna View). Segmental and total kinetic energies were calculated with the following mathematical formula:

$$E_kT(t) = \Sigma_i\,[\tfrac{1}{2} m_i V^2_{Gi/R}] + \Sigma_i\,[\tfrac{1}{2} I_i \omega_i^2]$$

(R corresponding to the referential of the bar).

RESULTS AND DISCUSSION: The first results concern the three conditions of speed. The kinetic energy of the inferior members (E_ki) is the major part (67.9% ± 0.92) of the total kinetic energy (E_kT), (Figure 2).

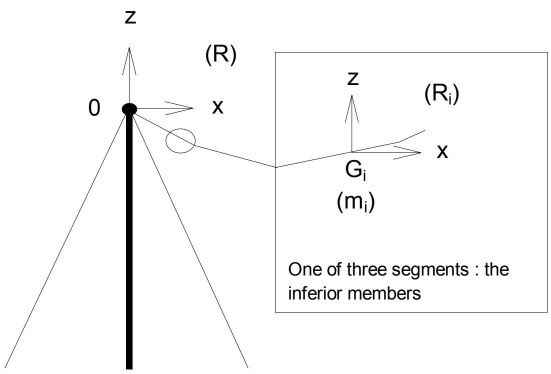
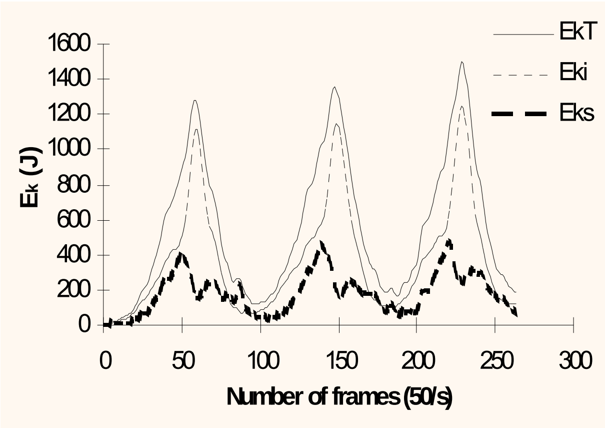


Figure 1

The calculation is made for each part of the body (i), with a mass (m_i), an inertia (I_i) and center of gravity (G_i), in the system of reference (R) of the bar. G_i moves with a linear velocity ($V_{Gi/R}$) and an angular velocity (ω_i).

Figure 2

E_kT : total kinetic energy, E_ki : kinetic energy of the inferior members, E_ks : kinetic energy of the trunk, head and superior members. Three rotations of backward giant swings at a fast speed (one subject). Ordinate in Joules, abscissa in number of frames (50 frames/s).



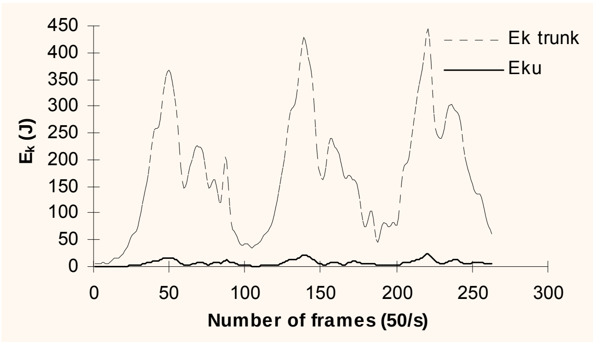


Figure 3

The upper members (E_ku), are a low percentage of E_kT (under all speed conditions: 1.39% ± 0.27) and show patterns similar to those of the trunk. Thus we think that the upper members, trunk and head can constitute only one segment: E_ks, (Figure 3).

The relation between E_kT and potential energy (E_p) shows (Figure 4) that the maximum value of E_kT, obtained in the lower part of the rotation, is always greater than the maximum value of E_p, obtained when the gymnast is at the top of the rotation. At this top of the rotation, the mechanical energy (E_m) is greater than E_p, because E_kT is different from zero. During the three rotations the minimum and maximum values of E_m increase with those of E_kT, whereas those of E_p are always similar.

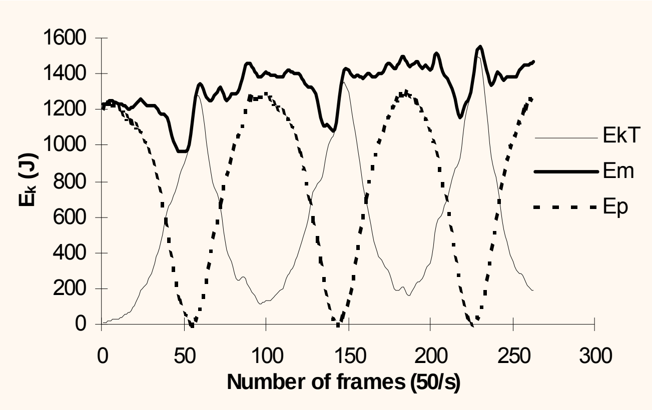


Figure 4

E_kT : total kinetic energy, E_m : mechanical energy, E_p : potential energy, Three rotations of backward giant swings at high speed (one subject). Ordinate in Joules, abscissa in number of frames (50 frames/s).

In E_kT, the rotational component is weak (between 2.6% and 3.2%). Between the different body segments the ratio is different (1% for inferior segments, 8.5% for superior segments). Therefore, the augmentation of mechanical energy (E_m) is due to the translational component.

During the diminution phase (Figure 2) E_ks systematically shows a break followed by a slide augmentation, after the maximum of amplitude, at the time of the maximum amplitude of E_kT and E_ki. This phenomenon may explain the augmentation of the total mechanical energy.

The second group of results corresponds to the comparison between the three speed conditions. In reference with the natural condition (N), the speed of the second rotation is reduced by 13.6% in slow movements (S) and increased by 19.6% in fast (F) movements.

In E_kT (Figure 4), the highest amplitude increases from the slow condition to the fast condition (between 15% and 35%). This is correlated with the lowest amplitude (Figure 5).

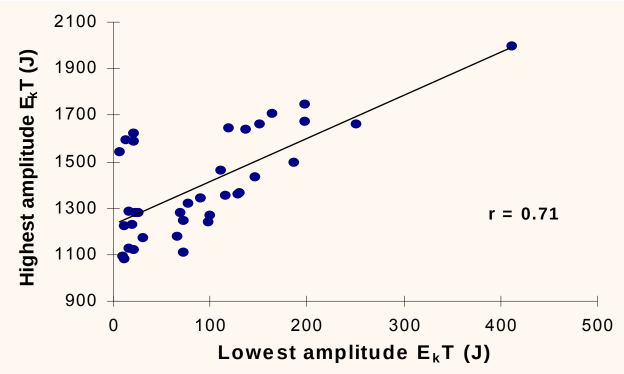


Figure 5

Correlation between the highest amplitude and the lowest amplitude of E_kT. The coefficient of correlation is 0.71. All experimental conditions and all gymnasts are represented.

Furthermore, the ratio $E_kT_{(lowest)}$ / $E_kT_{(highest)}$ increases with speed (Table 1).

	Slow speed	Normal speed	Fast speed
1^er^ rot.	1.01	1.43	1.38
2^e^ rot.	5.35	6.75	10.21
3° rot.	5.50	7.77	16.02

Table 1 : Ratio $E_kT_{(lowest)}$ / $E_kT_{(highest)}$ in percentages

These results mean that the lowest amplitude increases more than the highest amplitude, and particularly for the upper body ($E_ks_{(lowest)}$ / $E_ks_{(highest)}$, Table 2)

	Slow speed	Normal speed	Fast speed
1st rot.	1.14	1.91	1.99
2nd rot.	4.80	6.93	10.68
3rd rot.	4.01	7.66	22.33

Table 2 : Ratio E_ks $_{(lowest)}$ / E_ks $_{(highest)}$ in percentages

CONCLUSIONS: Although the major part of total kinetic energy was due to the lower limbs, the upper body seems to be responsible for the augmentation of total kinetic energy.

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