

COORDINATION OF SELECTED LEG MUSCLES DURING TAKE-OFF IN GYMNASTIC VAULTS

Serafin, R.; Siemanski, A.
Department of Biomechanics
Academy of Physical Education
Wroclaw
Poland

Take-off creates potential conditions for the realization of a vault. An increase of a degree of difficulty of gymnastic vaults has been achieved, among others, due to the improvement of the take-off conditions by regular introduction of flexible elements to the base and apparatus. Flexible elements of the gymnastic apparatus function as damping devices for man's motor system and on the other hand they are the external drives which in some circumstances assist muscle forces. Considering, that part of man's motor system that is skeletal muscles also show flexible properties it can be assumed that the result of a take-off depends on three kinds of forces: 1. muscle torques developed in joints, 2. forces originating from flexible elements of skeletal muscles actuating body segments, 3. forces originating from passive flexible elements of the base and apparatus. It should be pointed out that out of the two flexible elements represented by internal forces / muscle forces / and external forces / passive flexible elements / only the first ones have been examined. The technique of take-off from a flexible base may include the cooperation of passive and active flexible elements in two ways: summing - when resonance effect results from interaction between the two kinds of forces of the flexible elements, and differentiation - when the damping of the interaction of both force generators takes place.

The investigation of this problem starts with answering the question as to whether during a take-off from a flexible base there are phases of eccentric work of muscles engaged in it, that is, whether the accumulation and reutilization of elastic energy of skeletal muscles can take place / 1,3 /. Thus, the aim of the investigation was to examine the cooperation of skeletal muscles actuating hip joints, knee joints and ankle joints, and use the obtained results to determine phases of eccentric and concentric work of legs' muscles engaged in a take-off.

MATERIAL AND METHOD

The experiment consisted in performing two vaults: A - handspring forward vault, B - backward somersault after flic-flac. Both trials have been registered with a 16mm camera with the frequency of 100 frames per second in axis perpendicular to the course of movement, however, the attention was focused on the analysis of the take-off. Vault A was performed by a gymnast with the first sports class according to FIG classification and vault B by a gymnast with the second class.

In order to determine the phases of eccentric and concentric work of the muscles, first, muscle torques have been calculated / M_1 - for hip joints, M_2 - for knee joints, M_3 - for ankle joints / on the basis of the dependence between time derivative of the legs' angular momentum about a transverse axis of each of the three joints, and the total torque about the same axes. Siemanski et al /4/ Next, contraction velocities of three pairs of antagonist muscles / Il-m.iliacus, Gl-m.gluteus maximus, Brch-m biceps femoris caput breve, Vl-m.vastus lateralis, Tb-m.tibialis anterior, Sl-m.soleus/ have been calculated. These velocities were defined as time derivatives of the distance between their insertions and the anatomical data were taken from Prigo and Pedotti /2/. The contraction velocities depend on the angles φ , θ , ψ and angular velocities $\dot{\varphi}$, $\dot{\theta}$, $\dot{\psi}$ (Fig.1). The indication of eccentric and concentric muscle work corresponds to the relation taking place between the developed muscle torque in a joint and the contraction velocities of muscles contributing to that moment. The effect of extension in a joint may be the result of concentric work of extensors if the muscles actuating that joint are shortened the extending moment in a joint may be the result of tension of the stretched extensors, that is the result of their eccentric work.

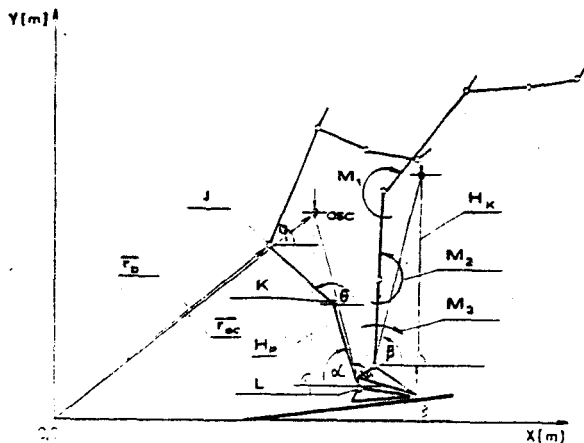


Figure 1. Position of gymnast in the resting reference frame XY for a vault \vec{r}_b , \vec{r}_{sc} vectors of hip joint and the centre of mass positions. φ , θ , ψ variables of position in the moving reference frame, M - muscle torques in wrists J.K.L., α , β - angles of take-off, H_p , H_k - centre of mass position in relation to L wrist in vertical axis.

RESULTS

Parameters α , β , H_p , H_k determined as in Fig.1 and maximum values of angular velocity $\dot{\varphi}$, $\dot{\theta}$, $\dot{\psi}$ together with corresponding angular positions in joints are presented in Table 1. Variables $\varphi(t)$, $\theta(t)$, $\psi(t)$ and $M_1(t)$, $M_2(t)$, $M_3(t)$ show angular displacements in the function of time in hip joints, knee joints and ankle joints and the time courses of muscle torques obtained for these displacements. /Fig.2/.

Senses of muscle torques for vault A are as follows:

1. Torque M_1 is negative if it is the extending moment in hip joints.
2. Torque M_2 is positive if it is the extending moment in knee joints.
3. Torque M_3 is negative if it is the extending moment in ankle joints.

Contrary to vault A torques M_1 and M_3 for vault B are positive if they are the extending torques in hip and ankle joints, and M_2 is negative if it is the extending torque in knee joints, which results from the choice of the reference frame for both vaults.

Positive construction velocity corresponds to shortening of a muscle. Analysis of geometry of the take-off in vault B shows that it is executed under a smaller angle in relation to the base than in vault A and it ends before reaching vertical position defined by the angle, whereas, vault A is characterized by higher values of angular velocities in joints and higher values of linear velocity of the centre of mass. The take-off in vault A is short and quick. Characteristics $\varphi(t)$, $\theta(t)$, $\psi(t)$, $M_1(t)$, $M_2(t)$, $M_3(t)$ presented in Fig.2 and respective velocities of muscles II, Gl, Bfcb, Vi, Tb, Sl served to define the phases of eccentric /ECC/ and concentric /CON/ work for the two vaults. The course of muscle activity corresponding to changes of angle in joints for vault A is as follows: Gl muscle generating the extending moment passes from eccentric work at the beginning of the take-off to the concentric one. Sl muscle, which passes from eccentric work at the beginning of the take-off to the concentric one in the final phase of pushing up the foot from the base, works synchronically with Gl muscle. In the phase of maximum flexion of the knee joint there comes to the eccentric work of Vi muscle and the transition to concentric work during the extension of the three joints of a leg simultaneously. In that position of maximum flexion of knee joints and ankle joints the effect of simultaneous eccentric work of the three extensors of a leg Gl, Vi and Sl can be noticed.

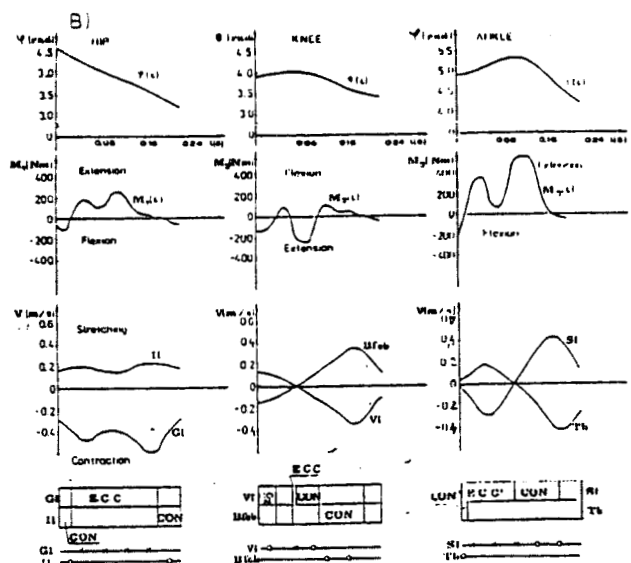
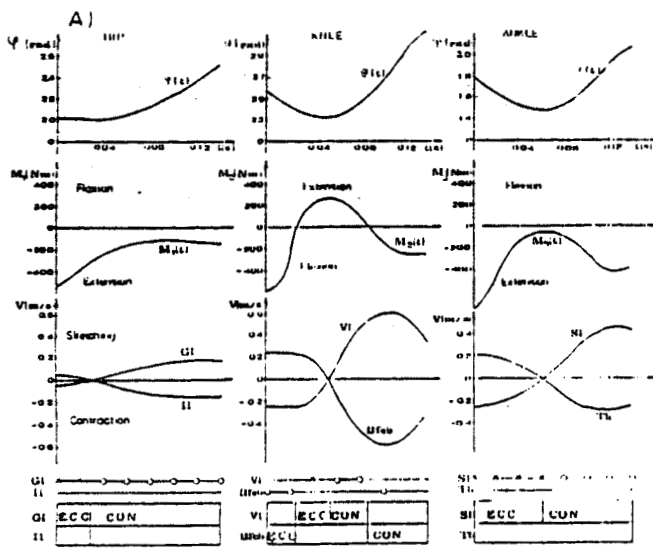


Figure 2: Characteristics of leg muscle cooperation in take-off, A - forward vault, B - backward vault. φ , θ , ψ - variables of position in joints, $M(t)$ - courses of muscle torques, Gl, Vi, Sl - velocities of contractions of leg extensors, Il, Bfcl, Tb - velocities of contraction of leg flexors.

TABLE 1

Take-off kinematic values. A - forward vault take-off. B - backward vault take-off. α, β in degrees V_i m/s, H in m φ, θ, ψ in rad, $\dot{\varphi}, \dot{\theta}, \dot{\psi}$ in degrees.

	α	β	V_p	V_k	H_p	H_k	$\dot{\varphi}$	φ	$\dot{\theta}$	θ	$\dot{\psi}$	ψ
A	-64	74	7.8	7.7	.93	1.16	6.2	46.3	13.2	25.8	11.8	70
B	-43	-84	5.3	6.5	.8	1.21	8.1	22	7.5	29	1.3	97

Such an effect was also found while analysing muscle cooperation in the take-off in vault B although this case differed noticeably from the previous one. The backward vault is accompanied by the evident eccentric work of the GI muscle, and at the beginning and at the end of the take-off phase there comes to concentric activity of the II muscle. It is in accordance with knee joints and ankle joints /first phase of a take-off/ there comes to the simultaneous eccentric work of GI, VI and SI muscles and these muscles pass to concentric work. Concentric activity of Bfcb muscle in the second phase of the take-off is not desired and its appearance may be interpreted as the lack of precision in the course of movement.

CONCLUSIONS

The characteristic of leg muscle cooperation allows one to formulate the thesis of interaction between the elements accumulating elastic potential energy in man's motor system and the elements accumulating potential energy in the flexible base. This statement is supported by simultaneous appearance of the phases of legs' extensors' eccentric work in three different joints at the moment directly preceding the achievement of maximum torques driving the body in the critical phase of the take-off. Acceptable variants of the cooperation of the flexible elements in man's motor system and passive flexible elements of the flexible base are as follows: all elements accumulate elastic potential energy, then its release takes place in the proper phase of the take-off and only some elements accumulate the elastic potential energy which results in its dispersion. In practise, such an effect of energy dispersion is known and is identified with the incorrect take-off technique.

The external manifestation of the incorrect take-off technique is the deformation of the flexible elements of the elastic base and the lack of a push up of the legs in the final phase of the take-off. However, it seems that this problem is complicated and the utilization of the elastic potential forces refers to the man - base system in which both man and base include elements accumulating and releasing elastic potential energy.

The time courses of coordination of muscles actuating a leg during the take-off is realized mainly by the eccentric-concentric work of the extensors. The extensors are subjected to eccentric work in the phase when the torques developed by them in joints generate the movement of extending legs, which causes the deformation of the elastic base. In the proper phase of the take-off the extensors pass to the concentric work.

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