TORQUES AND SYNCHRONIZATION OF MUSCLE WORK IN LEG IN THE MARATHON RUN

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Fatigue as a result of long term physical effort may influence the movement technique as well as the sense of muscle work and muscle coordination. In the present research the work of muscles of the lower extremity during the final kilometers of the marathon run is investigated. According to BUCKALEW (1985), who has investigated female runners participating in the marathon at Los Angeles Olympic Games, the greatest changes in running technique appeared between the 32th and 38th km of the distance. For the purpose of this paper the technique of several runners at the 38 km point in the Sleza Marathon was investigated.

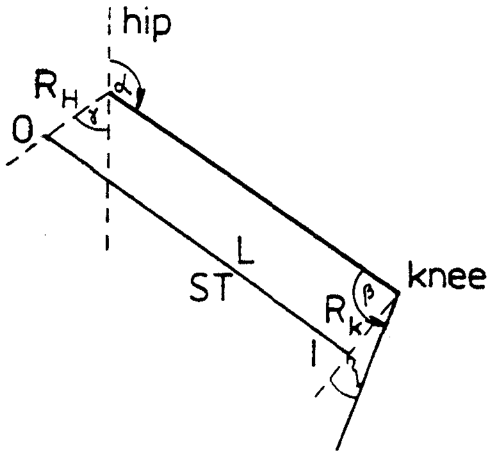
MATERIAL AND METHOD

The "Sleza Marathon" is for amateurs only. Four students nonpracticing competitive sports and participating in this marathon were investigated (Tab.1).

TABLE 1
Subject's data

Subject	Body height [cm]	Body weight [kg]	Performace
I	175	62	3:51:08
II	178	58	3:55:54
III	174	68	3:29:31
IV	182	72	3:38:58

The analysis of muscle work and calculation of torques in the hip and knee joints were based on the data collected by using the cinematographic method only. The camera set at 100 frames per second was used to film the full cycle of the running stride of the subjects at the 38 km point of the marathon distance. After the data collection and reduction, the torques in the hip and knee joints during the swing phase as well as the contraction velocity of selected muscles of the hip and thigh were calculated. A method similar to that suggested by FRIGO and PEDOTTI (1978) and FIDELUS at al. (1983) was used in order to calculate the contraction velocities of the mucles operating the hip and knee joint. Four biarticular muscles: rectus femoris, semitendninosus, semimembranosus and biceps femoris caput longum, and four monoarticular muscles: gluteus maximus, iliacus, vastus lateralis and biceps femoris caput breve were taken into consideration. Figure 1 presents, as an instance, the way of calculating the contraction velocity of the semitendinosus muscle.



$$V(\alpha,\beta,\dot{\alpha},\dot{\beta}) = \dot{L}(\alpha,\beta) \approx -R_H\dot{\alpha}\sin(\gamma-\alpha+\pi) +$$

$$+ R_K\dot{\beta}\sin(\beta-\zeta)$$

Figure 1: Calculation of contraction velocity for musculus semitendinosus

The moments of the muscle forces that have an effect on the hip and knee joints were calculated with the help of the relationship between the time derivative of a generalized momentum and the magnitude of the associated generalized force (SIEMIENSKI et al., 1987). It is rather difficult to apply this method for the support leg and that is why the torques in the hip and knee joints were calculated for the swinging leg only. The phases of concentric (positive) and eccentric (negative) work of a muscle were identified by comparing the torque-time history with that of the velocity of contraction of this muscle.

RESULTS

The general kinematic data of the running stride of the filmed subjects at the 38 km point of the marathon distance are presented in table 2. The muscle moments of force developed by the marathon runners at the hip and knee joints during the swing phase have values similar to those given by WINTER for jogging (1983) and about 2-3 times as small as the values obtained in sprint (BOBER and SIEMIENSKI, 1988)

TABLE 2
Kinematic characteristics of 10 km run (SUSANKA et al., 1986), women's Marathon (BUCKALEW, 1985) and own data

	10 km Men	Marathon Women	Marathon "Slezan" I	II	III	IV	Sprint
Velocity [m/s]	6.0	3.7	3.5	3.8	3.4	3.6	8.7
Frequency [steps/s]	1.64	1.52	1.39	1.52	1.56	1.35	4.54
Step Length [m]	1.84	1.23	1.23	1.27	1.08	1.24	1.91
Step Lenght BH	-	0.74	0.70	0.72	0.62	0.68	1.06
Nonsupport Time [s]	0.13	0.095	0.12	0.08	0.08	0.09	0.12
Support Time [s]	0.18	0.23	0.23	0.25	0.24	0.28	0.10
Support/ Nonsupport Ratio	1.38	2.45	1.91	3.13	3.00	3.10	0.83
Vertical Displace-ment of CM [cm]	-	6.2	10.0	8.6	6.5	8.4	-

TABLE 3
Maximum torque [Nm] in the hip and knee joints in the swing phase of running

	Hip ext.	Hip flex.	Knee ext.	Knee flex.
Marathon				
I	66.9	78.9	20.6	41.2
II	80.3	82.4	22.6	47.7
III	82.2	88.7	30.9	37.1
IV	89.3	153.0	27.8	39.3
Jogging /WINTER,1983/	60	80	40	40
Sprint /VAUGHAN,1984/	200	200	160	250

After close examination of the respective values obtained in marathon and jogging, one may notice that the moments acting at the hip joint are bigger in marathon, and the knee flexion movement is much the same but the knee joint extension moment is about 1.5-2 times as big as in jogging. It confirms the fact that knee extension movement during the swing phase is much more

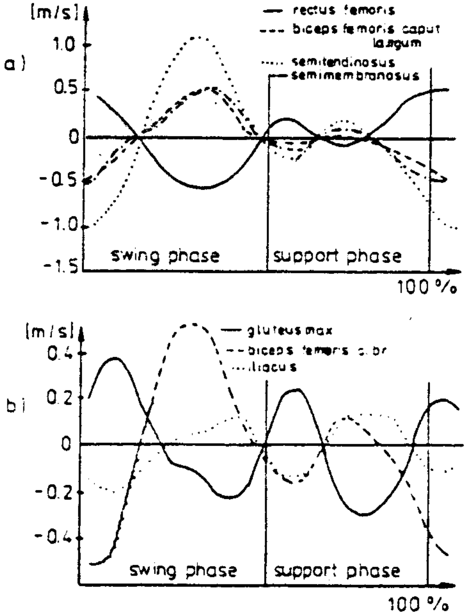


Figure 2: Contraction velocities of a/ mono- and b/ biarticular muscles in the marathon

passive and is caused by the shank gravity force. Figure 2 presents, as an example, the contraction velocities of mono- and biarticular muscles in the hip girdle and thigh in the marathon. The length of the muscles considered changes at a faster rate in the swing phase than in the support. A particularly big difference is noticeable in case of biarticular muscles, it is caused by their compatible work in either joint. The contraction velocity values for the mono- and biarticular muscles considered are in the swing phase in marathon about twice as small as in the same phase of sprint.

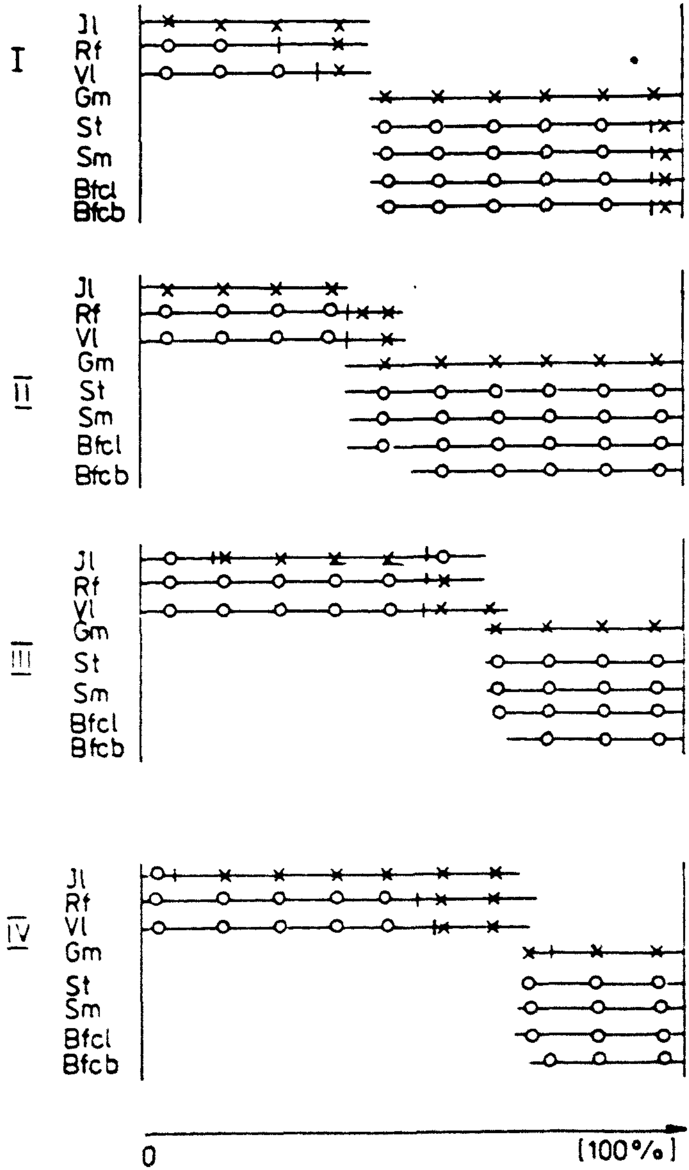


Figure 3: Periods of concentric /-x-x-x/ and eccentric /-o-o-o/ work of muscles in the swing phase in marathon. Il- iliacus, Rf- rectus femoris, Vl- Vastus lateralis, Gm- gluteus maximus, St- semitendinosus, Sm- semimembranosus, Bfcl- biceps femoris caput longum, Bfcb- biceps femoris caput breve

Figure 3 presents concentric and eccentric work periods of eight muscles of the pelvic girdle and thigh in the swing phase in marathon. The change of the sense of muscle work from negative to positive may be connected with the storage and reutilization of the muscle elastic energy. It follows from CAVAGNA'S research /1977/ that the elastic energy reutilization and adding this value to the general running efficiency takes place when the running velocity is higher than 7m/s. With this criterion as a base, one may state that the reutilization of the elastic energy is not possible in marathon. However, the work coordination of two muscles: rectus femoris (hip joint flexor and knee joint extensor) and vastus lateralis (knee joint extensor) makes it possible to use this kind of energy. It follows from the cooperation of these two muscles that the elastic energy storage and recovery may occur in relation to the knee joint movement when the braking of its flexion takes place after springing and, then, extension takes place. A relatively high (about 0.5 m/s) extension velocity of the muscle considered supports such a hypothesis.

CONCLUSION

The method of the analysis of the lower extremity muscles work during the swinging phase of running is based totaly on the cinematographic data. It made it possible to undertake such an investigation directly during the competition. However, the difficulties connected with the calculation of torques acting in joints during the support phase limited the application of this method. The analysis of the lower limb muscles work in the swing phase revealed that there is a possibility of the muscles elastic energy reutilization in some movement phase. However, the problem of actual reutilization of this kind of energy requires further research.

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