

Relationship between sprint time and quadriceps muscle characteristics from four subject groups, differing in neuromuscular performance demands

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INTRODUCTION

The 100 m sprint is one of the premium athletic events in the Olympics. Although it is commonly accepted that genetic determinants are important, only little knowledge about the complex biology of world class sprinters is known. One of a few papers reported a significant negative correlation between the percentage of type II muscle fibres in the M. quadriceps femoris and sprint time (Mero et al., 1981). From various studies we have learned that the mechanical properties of muscles are dependent on the specific recruitment and innervation frequency of their units and that muscle plasticity as a consequence of specific training schemes can be enormous (Enoka, 1996; Pette and Staron, 1997). There is little knowledge about the innervation strategies of individuals trained in special sport disciplines, but there are numerous studies which reported that long distance runners have about 72% type I fibres in their quadriceps, sprinters 31% and volleyballer, high- and long-jumper as well as untrained persons about 48% (for overview see Hering, 2001). The aim of this study was to examine the anthropometric, mechanical and neurological muscle properties from four groups of subjects, in order to relate them to the subjects 100m sprint time.

METHODS

EMG measurements were taken from the M. quadriceps femoris of volleyball players (first national league), sprinters (100m best time $M = 10.8s$), marathon runners (42,2km best time $M = 2.40 h$) and not specifically trained students of our physical education department in 6 different test procedures under isometric conditions. All subjects completed successfully two different isometric explosive tests (ET1/ET2) after beginning with a maximum force measurement (MVCT) followed by a patellar tendon reflex test (PTRT). The test battery finished with a relaxation (RT) and a fatigue test (FT). For the explosive as well as for the relaxation tests five trials and for the MVCT and PTRT only 3 trials were taken from 4 groups with 12 subjects ($N = 4 \times 12$). In ET1 the subjects were told to extend their right knee as fast and as strong as possible whereas in ET2 they had to contract only with the association "explosiv" without any torque demands. Trials in ET1 were only accepted above 85% of the maximum torque (T_{max}) measured in the MVCT before. The subjects performed in FT at each force level from 10% of the maximum voluntary contraction (MVC) to 90% MVC 10 trails (5 seconds of contraction) with a rest of 5 seconds in between until the required force could not be achieved any more. For interindividual comparisons torque was calculated as a product of the measured force with the distance between the insertion point of the force transducer and the chink of the knee joint. The tibia length was defined as the distance from the medial side of the knee joint to the medial maleolus.

The hip angle and the knee angle as well as the angle between the force transducer system and the lower leg were kept at 90 degrees. Via biofeedback the subjects were able to control the EMG and force development. Two bipolar surface electrodes with an interelectrode distance of 10 mm were positioned at the distal site of the vastus medialis (VM) and the middle of the rectus femoris (RF). To take measurements of the muscle fibre conduction velocity (MFCV), a special electrode assembly was placed between the motor point and the tendon insertion of the vastus lateralis (VL) The electrodes were repositioned until a maximum correlation between the two EMG signals could be found (mean $r = .99$).

The skin was prepared until the impedance was below 20 kOhms. The signals were recorded at a frequency of 5 kHz and stored after AD-conversion on a PC. Force and EMG data

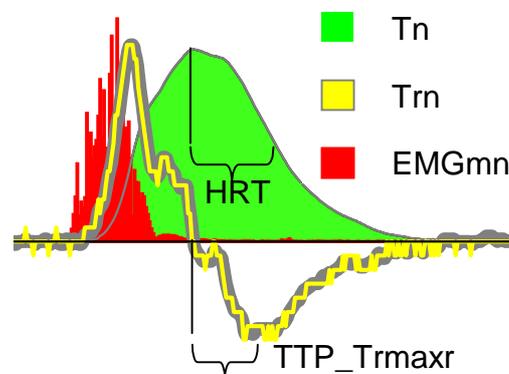


Figure 1: Typical Test ET2 (association "explosiv"); Tn = normalized torque; Trn = normalized torque rate; EMGmn = normalized rectified and averaged EMG of the vastus lateralis, medialis and rectus femoris; HRT = half relaxation time; TTP_Trmaxr = time to peak of the maximum torque rate of the relaxation phase

were automatically evaluated by a software package especially developed for this study. About 565 parameters were calculated. The EMGs of the VM, the VL and the RF were integrated from the beginning of the neural activity over a period of time which was identical with the time to peak of torque (TTPT). Both EMGs and torque values were normalized. The EMGs at the maximum EMG-Amplitude of the MVCT and the torque measurements at the maximum torque of the MVCT. The mean power frequency (MPF) of the EMGs of the three heads of the quadriceps was calculated for the same period. All parameters were first evaluated for each trial and then averaged to intra- and interindividual means.

RESULTS

1. Neither thigh girth nor any of the evaluated absolute and normalized positive force parameters in the different tests showed significant correlations to the 100m sprint time and this was true for all groups and over all subjects. Only the rate of force decline (negative force development) in ET1, ET2 and RT showed for some parameters significant relations.
2. The amplitude of the reflex EMG (EMGmax_PTRT) revealed a significant correlation to the 100m sprint time within the sprint group and across all subjects. The EMG reflex amplitudes of the sprinters were significantly reduced compared to the non specific trained sport students.
3. While there were no correlations between the sprint time and the normalized isometric force development, the force and time parameters (HRT and TTP_Trmaxr) which describes the ability for fast relaxation correlated highly with the 100m time.

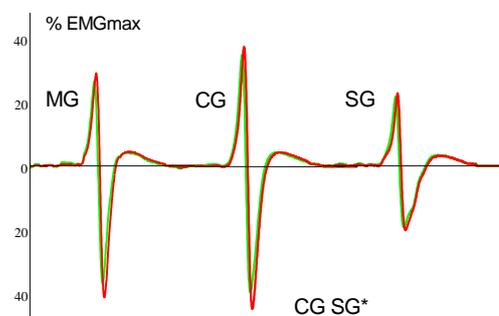


Figure 2: Averaged EMGs of the patellar tendon reflex for the marathon group (MG), the control group (CG = sport students) and the sprint group in PIRT. The averaged reflex - amplitudes are identical to the means calculated with the EMG-maxima of each trial; green/red line = channel 1/2 of the 2 channel EMG-electrode; * = $p < 0.05$

Significant correlations between the 100m sprint time and	N = 12	r	p =	N = 37	r	p =
EMGmax_RT	SG	0.69	0.039	all	0.48	0.012
TTP_Trmaxr_ET2	SG	0.62	0.014	all	0.50	0.002
HRT_ET2	SG	0.78	0.003	all	-	-
MPFm_ET2	SG	-0.57	0.050	all	-	-
MPF_10%m_FT	SG	-0.64	0.034	all	-0.37	0.042
MPF_20%m_FT	SG	-0.72	0.012	all	-0.35	0.053
MPF_30%m_FT	SG	-0.77	0.005	all	-0.40	0.024
MPF_40%m_FT	SG	-0.74	0.009	all	-0.33	0.063
MPF_50%m_FT	SG	-0.71	0.013	all	-	-
MFCV_40%_FT	SG	-	-	all	-0.44	0.017
TL/BH	SG	0.61	0.046	all	0.35	0.030

Table 1: Correlations between the 100m sprint time and reflex-, relaxation-, frequency- and anthropometric- parameters; MPF_10%40%m = Mean Power Frequency as a mean of the vastus lateralis, medialis and rectus femoris at 10 to 40% of the maximum torque

the differences were not significant. Only for the endurance test there was a significant negative correlation between the MFCV at 40% MVC and the 100m time calculated over all available data.

6. There was a surprising significant correlation between the sprint time and the tibia length normalized at the subjects body height (TL/BH) within the sprinters and over all subjects.

Diskussion

The correlations of the Reflex-EMG, the MPF and the relaxations parameters with the 100m sprint time suggest a dominant role of neural recruitment and innervation strategies for the sprint technique.

Both, the force and the discharge frequency of the units are dependent on the innervation frequency of the

4. Within the sprint group there were significant negative correlations between the Mean Power Frequency (MPF) and the 100m sprint time, especially for the explosive (ET2) and endurance test procedures (FT).
5. The propagation velocity of the action potential, the so called muscle fiber conduction velocity (MFCV), was the highest in all test procedures for the sprinters followed by the control group and the marathoners. But

T-Test grouped according to the 100m-time of the sprinters (SG)				
Mean fast = 10.6s ; N=6 / Mean slow = 11.03s; N=6				
		Mean 10.6 s	Mean 11.03s	P <
MVCT:	MPF_VL_MVCT	105.08	80.15	0.009
	MPF_RF_MVCT	135.60	102.48	0.004
ET1	MPFm_ET1	106.22	86.20	0.019
ET2:	MPFm_ET2	101.07	82.03	0.016
RT:	MPFm_RT	117.95	94.92	0.012
FT:	MPF_10%m_FT	118.16	95.80	0.006
	MPF_20%m_FT	119.84	96.73	0.001
	MPF_30%m_FT	122.38	100.81	0.003
	MPF_40%m_FT	121.41	98.73	0.003
	MPF_50%m_FT	118.73	92.77	0.013
	MPF_60%m_FT	117.15	86.21	0.011

Table 2: The MPF of the 6 fastest sprinters was significantly higher in all test procedures in comparison to the others.

supplying motor neurons (Botterman et al., 1986). The discharge rates of single motor units, measured with wire electrodes, shows clear relations to the mean power frequency (MPF) of the surface EMG (Fuglsang-Frederiksen & Ronager, 1988; Moritani & Muro, 1987). Because of the higher discharge rate and the more narrow action potential shape there is a relationship between the content of fast twitch fibers (FTF) and the MPF at the M. vastus lateralis (Gerdle et al., 1991; Wretling et al., 1987).

According to the results of Mero (1981), under this considerations, the 6 best sprinters who had a significant higher MPF compared to the others, seemed to have more FTF in the VL. But why is no significant negative correlation between the 100m-time and the torque-time parameters in the phase of force development? The answer is: "In a concentric contraction, when the FT-fibers are recruited earlier or before the slower fibers, they stretch the elastic tissue because they are ending mid-fascicularly, usually at one end and sometimes at both ends. This is in contrast to the slow twitch fibers (STF) which tend to span the distance between the connective tissue inscriptions demarcating the fascicle and terminated as blunt endings into the connective tissue interface (Roy & Edgerton, 1992).

Based on this assumption, in conditions where the elastic tissue is already stretched out there must be a difference in force development or decrease for those athletes with a higher portion of FT-fibers. And in fact there is a significant correlation for the relaxation parameters HRT and TTP_T_{maxr} for the sprint group as well as for all subjects. Whereas during the force development the FT-fibers stretch the connective tissue faster than the ST-fibers, during the relaxation phase they are responsible for the early force decrease. FT-fibers are characterized by a highly active Ca²⁺ - ATPase (SERCA1a) and a high concentration of parvalbumin (Pette & Staron, 1997). Both proteins are responsible for the fast decrease of the Ca²⁺ - concentration in the muscle cells.

Beside the relaxation, under eccentric conditions the force development of the FT-fibers is assumed to be effective too, because the elastic network is stretched out by external forces. Measuring under isometric conditions, this can't be shown by our data, but there is a significant correlation between the amplitude of the reflex-EMG and the sprint time, revealing an indirect relation to stretch contractions.

Häkkinen and Komi (1986) found significantly reduced EMG amplitudes for the patellar tendon reflex after an eccentric training over a 24 week period and Casabona et al. (1990) found the H-reflex of volleyballers and sprinters significantly reduced. Possibly the reduction of reflexes is an index for a better intra muscular coordination in the sense of presynaptic inhibition of the slower motor units as a presumed prerequisite of a selective recruitment of FT-fibers (Nardone et al., 1989). This could be a benefit in the very short contact phase which only lasts about 20% of the whole sprint cycle. 80% during a sprint step is needed for the swing phase.

Because of the energy costs and the important role of the mass inertia during the swing phase, the distal extremities of fast running and jumping animals are all slender and can be fold up extremely when the leg oscillates forward. A smaller relative tibia length for sprinters would reduce mass inertia in the swing phase and could explain the significant correlation to the sprint time.

In conclusion, for sprinter the quality of neuromuscular processes seem to be much more important than the muscle mass by itself.

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