FORCE- AND POWER- TIME RELATIONSHIP, EMG RESPONSES IN CONCENTRIC AND ISOMETRIC CONDITIONS. EFFECTS OF TRAINING AND INDIVIDUAL CHARACTERISTICS

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INTRODUCTION

The relationship between EMG and the biomechanical parameter in isometric and dynamic muscle tension represents an essential method in the analysis of the specificity of training effects and of the individual characteristics (De Luca 1982, Schmitbleicher 1981, Solomonow 1990, Viitasalo 1982, Westing 1991). The objective of this study was to investigate the relationship between the biomechanical parameters and the EMG responses during extension of the arms (push-off) under defined biomechanical constrains.

METHODS

A special sliding-sledge arm dynamometer (40° inclination) was used for testing and training purpose (see Alberti, Roi Selvaggi and Giovannelli in this book). Force-, power- and velocity- time relationships of maximal voluntary contraction (MVC), under concentric and isometric conditions (90° at elbow joint), with and without preloading were determined.

Force development indicators were calculated by: differentiation of force-time curve (RFD), quotient between the half maximal force (F50%) and the corresponding elapsed time (RFD50), quotient between Fmax and corresponding time interval (SFI).

For EMG purpose, surface electrodes (diameter=5 mm; inter-electrode distance 40 mm) were placed over the belly of each muscle (Tric.br=TB.; Bic.br.=BB; Delt.an.=DA; Pect.ma.=PM). Bipolar myoelectrical potentials were recorded; signals were preamplified and band-pass filtered (CMRR>= 70 db, BP=10 Hz- 1 KHz; Zin=1,5 M . gain= 1000). EMG signals and the force were digitized on-line with a sampling frequency of 1000 Hz. Root-mean square (RMS) of EMG signals was calculated to obtain envelop curve patterns of each muscle. To obtain IEMG, integration of the RMS-EMG signals was performed over fixed time intervals (- 50 ms to 100 ms and to 500 ms from onset of force development). Power spectra analysis (median frequency MF) was carried out using 1024 and 512 data points.

Two groups (n=8) of sport students were involved in the training experiment. Subjects performed a 8 weeks training period (2 times per week) under different loading conditions (only on the dynamometer 5 x 8 rep.; or in combination with classical bench press exercise 5 x 5 rep.).

Basical statistical methods were employed to obtain mean, standard deviation, and differences were tested for significance ($p<0.05$) using dependent and independent Student's t test.

RESULTS

The results of a test session occurred after 4 weeks of training and for a reduced number of subjects are presented.

Mechanical Output Dynamic Tests

In fig. 1 the relationship of Fmax, Pmax and Vmax with respect to the load conditions is shown. Velocity decreases with increasing load as expected. Nevertheless, force and power peak values show less variation over the loading range considered. Also taking into account the normalized power peak values (in percent of the individual maximum) only few subjects denoted a consistent decrease in respect to the load of 60 % of maximum. The average power also showed a clear levelling-off over the loading range. For the force peak value we found tree main tendencies: 1) a linear increase with load up to values near to the MVC; 2) linear increase with best values 80% of MVC; **3)** levelling-off at about 85% of MVC in concomitance with load of 50% of maximum.

The time necessary to reach peak values showed a linear increase in respect to Vmax for all subjects (Tab. I). However, the time to Fmax was almost constant with except for some subjects where a non linear increase (from a load of 70% of maximum) were observed. A consistent stability for time-to-Pmax and Fmax ,350 ms and 160 ms respectively. were found for subject S.D. and these were the lowest values registered.

Mechanical Output Isometric Tests

The maximal isometric force (Fmax) was lower when produced from preloading. For a higher decrease of RFD (60%) in the preloading range of 20% to 50% there was a smaller decrease in the Fmax (15%). RFD and RFD50 are very consistent when expressed as percent of the individual maximum (VIITASALO 1982).

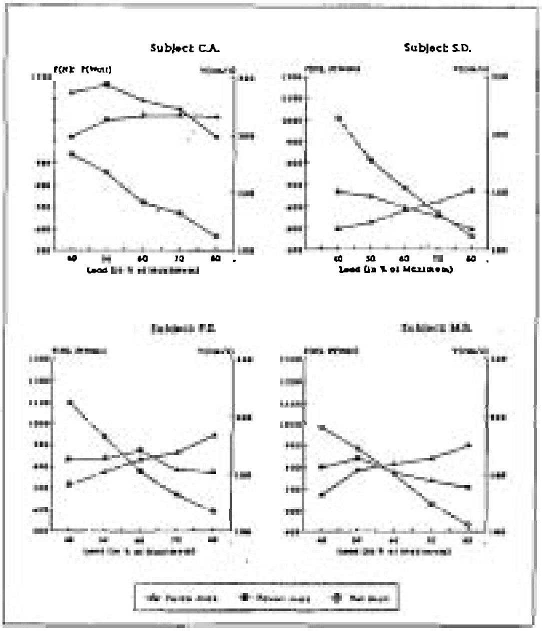

FIG.1. maximal force, power, and velocity in relation to load mass of the slcdgcd in concentric efforts.

Load (% Max)	Var.		Subjects C.A.	P.S.	S.D.	M.R.
	Fmax.	(*)	183	165	140	192
40	Pmax.		433	325	245	437
	Vmax.		566	515	425	577
	Fmax.		215	175	130	215
50	Pmax.		433	380	360	542
	Vmax.		612	575	510	670
	Fmax.		220	200	155	204
60	Pmax.		462	475	345	577
	Vmax.		662	655	600	723
	Fmax.		315	225	150.	184
70	Pmax.		580	600	335	662
	Vmax.		735	745	660	790
	Fmax.		575	210	165	197
80	Pmax.		705	715	350	792
	Vmax.		810	775	730	891

Tab. 1. Time (ms) to reach peak values
(*) mean values

EMG - Isometric Tests

IEMG values increased with increasing preloading. Nevertheless, subjects with less experience in the training and testing device showed an inverse tendency especially in respect to TB and DA (fig. **2).** Interesting was the inversion in the levelling off between the prime motors TB and DA when preloading reached high level. This was more evident for the 500 ms analysis period (fig. 2 P.S.). TB showed the highest increase of activation whith respect of both the analysis periods of 100 ms and 500 ms respectively.

In the EMG spectral analysis there were significant differences for the median frequency (MF) especially referring to TB. Subjects with high MF values for TB showed also high RFD values, however, significant RFD values were found in subject with relative lower MF.

EMG - Dynamic Tests

The EMG pattern appear as a typical extensor sequence with concomitant activation of TB, DA and PM as synergists.

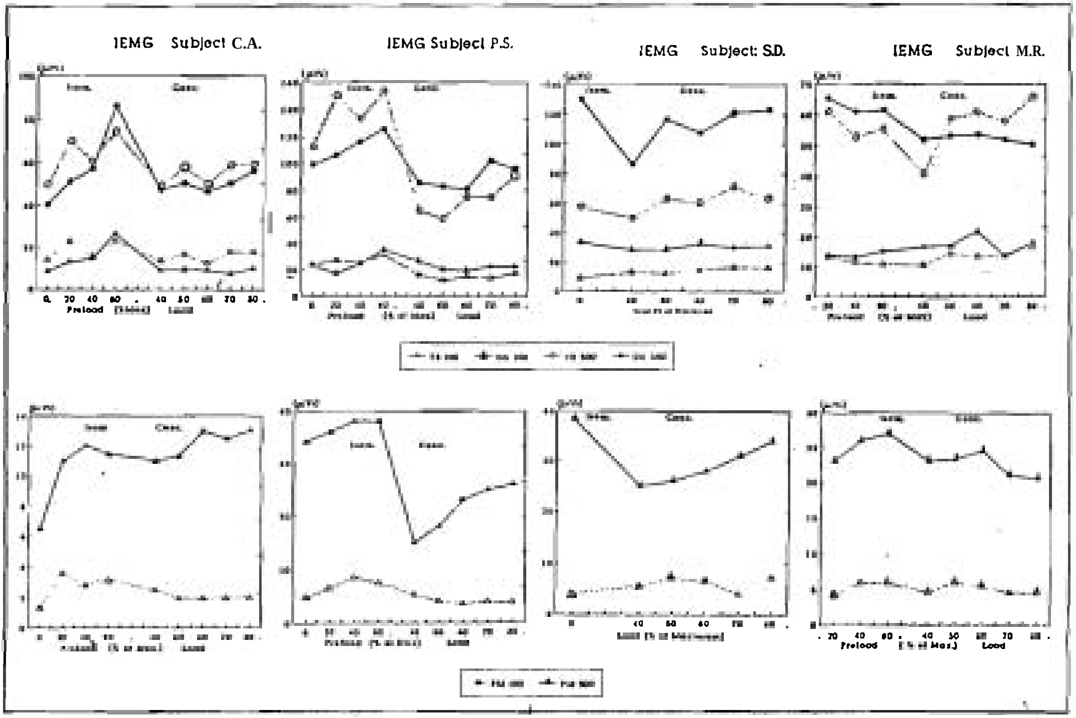

FIG. 2. IEMG values of the prime movars TB, DA and PM in relation to pretension (preload) during isometric efforts, and to load in concentric efforts. Values were calculated over two fixed time intervalls: - 50 to 100 ms and - 50 to 500 ms after onset of force development.

Burst of BB were observed with different evidence. In particular, following strategies could be found: **A)** maximal activation of TB and DA from the onset of force development and maintenance of a high level through the total duration of the push-off movement. Burst pattern of BB appears at the end of activation of the prime movers. B) A significant decrease of activation of TB or/and DA after an early agonist burst followed by a second relevant increase. C) Maximal activation is obtained not only for high levels of loading (60%-70%) and this is especially the case of DA. Occasionally there was a significant co-contraction of BB during agonist burst. IEMG values during the 100 ms and 500 ms periods were generally lower or equal to those obtained in the isometric MVC without preload. However, for some subjects there was an inverse tendency (fig. 2 C.A.). The intermuscular activation pattern, i.e. the distribution of the myoelectrical activation level between the muscles, seems to remain constant over the range of loading conditions, but an inversion at certain critical loads were also observed (fig. 2). Thus, there is a "dominance" in the level of activation for one muscle above the others, but this does not remain fixed over the loading range and with respect to the duration of the movement (i.e. inversion of dominance occurs from the 100 ms to the 500 ms analysis periods). This kinds of variation is also noted referring to the comparison with isometric MVC.

DISCUSSION

For subjects with different muscle fibres composition (FT vs ST) selective recruitment of motor units MUs, at different pretension levels, should have different effects in the tendency of RFD decline. Hihg MF values in the EMG power density spectra are related with recruitment of large MU (De Luca 1982, Solomonow 1990). On the other hand, it seems reasonable that subjects with high MF in MVC without preload are not able to activate fully the muscle in all types of voluntary muscle actions (Westing 1991).

EMG power spectra of TB and DA showed lower MF values for DA and this is in good agreement with the higher proportion of slow fibres for this muscle (Schmitbleicher 1981).

The specificity of the biomechanical constrains of an exercise as well the level of reserve in the control of neural drive are reflected in the unregular tendency of the IEMG-load relationship especially for subject with less experience in the training device (M.R.). Similar tendency in the mechanical output arc not necessary matching analogue variations in the muscular activation level and interactivity pattern. Subjects P.S. and C.A. showed similar IEMG trends in isometric test but an inversion during concentric tasks (fig. 2)

In conclusion the present investigation support the necessity to use integrated testing protocols for a correct interpretation of mechanism responsible for adaptation and for identify the most relevant parameter which should bc the "true" indicators in training schedules.

REFERENCES

- De Luca, C., LeFever R., McCue M., and Xenakis A. (1982).Behavior of human motor units in different muscles during linearly varying contraction. J Physiol. Lond. 329: 113-128
- Schmitbleicher, D., Haralambie G. (1981). Changes in contractile pro perties of muscle after strength training in man. Eur J Appl Physiol 46: 221-228
- Solomonow, M., et al. (1990). Electromyogramm power spectra frequencies associated with motor unit recruitment strategies. J Appl Physiol 68(3): 1177-1185
- Westing, S.H., Cresswell A.G., Thorstensson A. (1991). Muscle activation during maximal voluntary eccentric and concentric knee extension: Eur J Appl Physiol 62:104-108
- Viitasalo,J.T.(1982) Effects of pretension on isometric force production. Int J Sports Med 3: 149-152