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Conference Paper · November 2002

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INFLUENCE OF ISOMETRIC VOLUNTARY CONTRACTION ON TIME AND FREQUENCY DOMAIN PARAMETERS OF SURFACE EMG

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Abstract- The main objective of this paper was to investigate the effect of increase of isometric voluntary contraction (IVC) on surface EMG recorded from the Biceps Brachii (BB) muscle. Five different force levels (FL) were used: 10, 30, 50, 70 and 100% of maximum voluntary contraction (MVC), with each recording lasting 5 seconds. The following sets of parameters were extracted: (i) in the time domain (turns (ts) and zero crossings per second (zc)), and (ii) in the frequency domain (median frequency (fp), frequency at maximum power (fx), maximum power (Px), and total power (Pt)). A total of 91 normal subjects aged between 5 and 69 years old were analyzed. The Wilcoxon paired two-tailed test ($p < 0.05$), was used to classify changes in parameters examined as significant (S) or non-significant (NS) during transition from a force level to another. Results showed that: ts, zc, Px, and Pt increase with force whereas fp decreases with force. Moreover, these parameters showed significant difference between the different force levels examined.

Keywords - Surface EMG, isometric voluntary contraction

I. INTRODUCTION

Many researchers attempted analysis of surface SEMG. The most frequently examined parameters were mean power frequency (MPF), and to a lesser degree Power Spectrum (PS) shape and total power (Pt). However because results were often conflicting [1]-[5] and group samples examined were small in size, the advantages of SEMG have not been justified that well. The aim of this study is to investigate SEMG simple time and frequency domain parameters on a large group of normal subjects and investigate if they exhibit significant difference at different force levels.

II. METHODOLOGY

Ninety-one normal subjects aged between 5 and 69 years of age (54 male (m) and 37 female (f)) participated in this study. The subjects were divided in age groups as follows: 5-9 years, 12 subjects (7 m & 5 f), 10-19 years, 12 subjects (8 m & 4 f), 20-29 years, 20 subjects (10 m & 10 f), 30-39 years, 13 subjects (8 m & 5 f), 40-49 years, 12 subjects (7 m & 5 f), 50-59 years, 12 subjects (7 m & 5 f), and 60-69 years, 10 subjects (7 m & 3 f).

Recording set-up. Frequency settings were 20 Hz and 500 Hz for lower and upper cut off frequencies respectively and the sensitivity varied between 10 and 500 μ V/div, depending on the force level of each individual. The sampling frequency was 1000 Hz with 16 bits resolution and the duration of the signal recording was 5 seconds. Recording was carried out using a four-bar EMG active

probe with an interelectrode distance of 10 mm and a bar width of 1 mm. The electrode block was placed on the BB in such a way so that the second electrode was at a distance equal with 1/3 of the BB length towards the shoulder. Five different force levels (FL) were used: 10, 30, 50, 70 and 100% of maximum voluntary contraction (MVC).

Signal processing. Six parameters were analyzed: two from the time domain (turns (ts) and zero crossings per second (zc)), and four from the frequency domain (median frequency (fp), frequency at maximum power (fx), maximum power (Px), and total power (Pt)). Differences in the mean values of these six parameters were evaluated using the Wilcoxon matched pair rank test. A two-tailed significance level of 95% ($p \leq 0.05$) was used.

Time domain analysis. The number of ts was defined as the number of slope reversals separated from the previous and the following turn by an amplitude difference greater than 10 μ V. The number of zc was defined as the number of sign reversals exceeding a threshold of 10 μ V.

Power spectral analysis. This was computed by averaging segments of the signal of 512 points with 25% overlap. The fp divides the area under the PS area in two equal parts, whereas fx is the frequency at the highest PS peak. The Pt was calculated as the area under the curve and the maximum power Px was estimated as the highest value of the PS curve.

III. RESULTS

Table I summarizes the median, and in parenthesis the lower quartile (25%) and upper quartile (75%) range for all six parameters examined for each force level. The median and lower and upper quartiles are given due to the non-Gaussian distribution of the data investigated. Table II summarizes the results of statistical analysis of the Wilcoxon matched pair rank test between different force levels. In Table II, significant difference (S) is given if $p \leq 0.05$, whereas a non significant (NS) difference is given for $p > 0.05$.

As given in Table I results show that: ts, zc, Px, and Pt increase with force level, whereas fp decreases with force level. Moreover, these parameters showed significant difference between the different combinations of the force levels examined (see Table II). Feature fx showed significant difference only between 10 and 30% of MVC.

Figure 1 illustrates the median, lower and upper quartiles spread for each force level of the turns per second and the median frequency. It is clearly illustrated that there is an

increase of the number of turns per second with force level, whereas the reverse is true for the median frequency.

TABLE I MEDIAN, AND IN PARENTHESIS THE LOWER QUARTILE (25%) AND UPPER QUARTILE (75%) RANGE FOR ALL SIX PARAMETERS EXAMINED FOR EACH FORCE LEVEL

	10%	30%	50%	70%	100%
ts	34 (3-57)	75 (28-100)	92 (55-122)	105 (70-134)	121 (88-146)
zc	10 (0-44)	51 (7-81)	73 (36-102)	94 (49-108)	99 (78-116)
fp	104 (90-125)	101 (88-116)	99 (86-115)	95 (84-112)	93 (83-110)
fx	76 (64-96)	74 (63-83)	77 (67-93)	75 (65-91)	72 (64-88)
Px	0.24 (0.08-1.2)	0.92 (0.28-4)	2.8 (0.63-15)	5.03 (1.5-31.3)	18 (3.7-110)
Pt	9 (3-3.9)	31 (7.3-145)	85 (22-470)	190 (43-810)	560 (113-2460)

TABLE II RESULTS OF STATISTICAL ANALYSIS FOR EACH PARAMETER FOR THE WILCOXON MATCHED PAIR RANK TEST BETWEEN DIFFERENT FORCE LEVELS. SIGNIFICANT DIFFERENCE (S) IS GIVEN IF $p \leq 0.05$, WHEREAS A NONSIGNIFICANT (NS) DIFFERENCE IS GIVEN FOR $p > 0.05$

	ts	zc	fp	fx	Px	Pt
10-30%	S	S	S	S	S	S
10-50%	S	S	S	NS	S	S
10-70%	S	S	S	NS	S	S
10-100%	S	S	S	NS	S	S
30-50%	S	S	S	NS	S	S
30-70%	S	S	S	NS	S	S
30-100%	S	S	S	NS	S	S
50-70%	S	S	S	NS	S	S
50-100%	S	S	S	NS	S	S
70-100%	S	S	S	NS	S	S

Fig. 1 Median, lower and upper quartiles spread for each force level (shown in the x-axis as percentage of MVC) of the turns per second and the median frequency.

IV. DISCUSSION

The turns per second and the zero crossings were increased significantly with force for all subjects as well as the maximum and total power extracted from the power spectrum of the signals recorded. The median frequency showed a small but significant decrease in value with force, whereas the frequency at maximum power remained fairly constant with non significant difference between force levels except in the 10-30% transition.

Although the mean frequency was generally used by most of the studies, in this study the median frequency was selected for the following reasons: (i) it is more reliable

when examining signals affected with noise such as SEMG signals [4], (ii) since SEMG signals do not present the characteristics of a normal distribution, median frequency should be preferred [6], and (iii) mean frequency is more influenced from the low pass tissue filtering effect rather than the median frequency [6]. Similar findings to this study regarding the decrease of median frequency with force level were also reported in [7].

The change of the six parameters computed with age and gender was also investigated, however, non significant differences were identified.

The results of these study suggest that simple parameters, like the turns per second, the zero crossings per second, the median frequency, the power at maximum frequency and the total power differ significantly between the different transitions of 10, 30, 50, 70, and 100 of MVC. These parameters are currently evaluated on SEMG recorded from subjects suffering with neuromuscular disorders.

ACKNOWLEDGMENT

This work was made possible through the kind support of the Cyprus Institute of Neurology and Genetics.

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