Power spectrum analysis and conventional electromyogram in Duchenne muscular dystrophy

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ABSTRACT

Objective: A comparative study of automatic electromyogram analysis (power spectral analysis) and manual measurements of the individual motor units potentials parameters in normal and Duchenne muscular dystrophy patients was performed to assess the diagnostic yield of both methods.

Methods: The analysis of 20 motor unit potentials elicited at weak effort manually by visual assessment and by power spectrum analysis at 1400 Hz Haning window were performed with concentric needle electrode in the biceps brachii and tibialis anterior. The study includes 18 healthy controls and 32 Duchenne muscular dystrophy patients. The primary diagnosis of the patients was based on the clinical criteria, family history and serum creatin kinase activity estimation. Seventeen patients were biopsied for further histological and histochemical examination.

Results: The conventional electromyogram of the patient group characterized by condensed, low mean amplitude of the recruited pattern and an increase in the percentage of polyphasic potentials of short duration and low amplitude in comparison to the normal subjects. About 74% of the patients were identified as myopathic patients with this method. Power spectrum analysis showed significant increase ($P<0.0005$) in the mean power frequently and the relative power at 1400 Hz and a significant decrease ($P<0.0005$) in accumulated power. About 95% of the patients were identified as being myopathic patients by this method. Statistical correlation analysis revealed no relationship between the power spectrum analysis and motor unit potentials parameters.

Conclusion: The electromyogram power spectra was shifted to the higher frequencies in the Duchenne muscular dystrophy patients as compared to the control. The diagnostic yield of the electromyogram power spectrum analysis was higher than the measurement of the motor unit potential parameters. The best parameter of the electromyogram power spectrum is the relative power at 1400 Hz than the other two parameters. The net result of this study is that the electromyogram power spectrum has diagnostic possibilities in the muscles, which showed normal, or few motor unit potential changes.

Keywords: Duchenne muscular dystrophy, power spectrum analysis, conventional electromyogram, needle technique, biceps brachii, tibialis anterior.

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Assessment of the electromyogram (EMG) manually by the eye and the ear, and quantitative EMG of different motor unit potentials (MUPs) elicited at weak effort,[1,2] are routinely used in common practice in diagnosing myopathies.

In many occasions the pattern of the electrical activity of the dystrophic muscle recruited during full effort was similar as for formal muscles, only on closer inspection, the individual potentials appear shorter in duration and comes with short time

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intervals causing condensed interference pattern.[3] These ordinary methods are unfortunately unfavorable in diagnosing muscular dystrophies since one of the important features in these diseases is the appearance of a large number of MUPs at relatively low tension.[4] This makes the analysis of the individual MUP characteristics difficult.[5] Thus it is necessary to look for another approach, which involves the analysis of the pattern of the electrical activity at higher forces of contraction. This was achieved at first by the frequency analysis,[6] turns amplitude analysis.[4] Later on, with the development of microprocessors applying fast Fourier transformation, it was possible to analyze the power frequency on-line moment by moment with better resolution.[7]

Many studies deal with the frequency analysis and its value against the analysis of the individual MUP parameters in myopathic disorders. Some of them include analogue filters,[6] surface electrodes,[8] simple analogue octave band filters[9] and fast Fourier transformation[7,10,11] with contradictory results.[8,9,11-14]

The aim of the present study was to compare the results of power spectrum analysis and the manual MUPs analysis in the m. biceps brachii and m. tibialis anterior from patients with Duchenne muscular dystrophy (DMD).

Methods.

Subjects. The study includes two groups. The first group comprised 18 healthy boys with an age range between 6 and 12 years (mean ± SD = 8.55±1.85 years). The second group consisted of 32 DMD male patients aged 6-12 years (mean ± SD = 9.03±1.43 years). The duration of the illness was 1-5 years (taking in consideration the onset at the appearance of first clinical symptom). DMD is a well categorized and circumscribed entity could be diagnosed clinically and confirmed by its pathognomonic histochemical features.

Seventeen out of the 32 DMD patients underwent open muscle biopsy of 0.5 cm x 0.5 cm from the quadriceps femoris muscle. Tissue sections were processed for histological examination using Gomori's trichrome stain. Fresh frozen sections were used for histochemical evaluation using standard alpha naphthyl acetate esterase reaction. Care was taken to exclude the areas of EMG study. The m. biceps brachii and m. tibialis anterior of the right side were sampled. The electrophysiological examination was carried out in the Neurophysiology Unit-University Hospital. Dantec counterpoint 4-channel electromyography was used throughout.

Conventional electromyogram. The analysis involves 20 MUPs elicited at weak effort and picked up by concentric needle electrode (Dantec 13L58) with pick up range of 0.07 mm^2. The MUP duration, amplitude and shape and the interference pattern were studied.

Power spectrum analysis. The subject lay supine, the upper arm resting on the couch and the elbows in semi-flexed position and the forearm making an angle of 70 degrees with the arm. The ankles in equivocal position and projecting just beyond the end of the examination couch.

The subjects were asked to do voluntary contraction against the resistant force of the examiner attempted by flexion of the elbow when examined m. biceps brachii and dorsiflexion of the ankle during examination of the m. tibialis anterior. The percent of force applied was not measured apart from asking the subject examined to perform an effective volitional effort.[6,15]

Ten sites distributed over three insertions within each muscle were assessed. Between two recording epochs a few seconds of rest were introduced in order to avoid fatigue.[16] The electrical activity was analyzed at 1400 Hz Haning window from each scan averaged spectrum, mean power frequency (MPF), relative power at 1400 Hz in part per million of the total power (ppm) as well as accumulated power.[7,11]

Statistical analysis. The results were expressed in mean ± standard deviation (SD). Differences between two groups were evaluated with Student's T test. The percent of abnormal values in any test is calculated as above or below (mean ± 2.5 SD) of the normal values for the control group.

The results were considered statistically to be significant when the level of significance "P" was accepted to be equal or less than 5%.

Results.

The patients were clinically examined and diagnosed by a consultant neurologist at the time of presentation. No correlation was carried out between the different stages of the disease neither clinically nor electrophysiologically.

Twenty-three patients presented with hypertrophy of the lower limb muscles while only nine with hypertrophy of the upper limb. Wasting of the upper limb muscles was present in 6 patients versus 2 patients with wasting of the lower limb muscles. Wasting of the lower limb muscles was present in 2 patients whereas 6 patients had wasting of the upper limb muscles.

The proximal muscles were affected in all the patients whether the examined limb was the upper or the lower one. Moreover, 10 and 17 patients in whom the distal muscle of the upper and lower limbs were affected, the lower limbs were the first to be affected in 28 patients; the upper limbs in 4 patients while the bottom upper and lower limbs were affected in 18 patients.

The mean value of CK in the normal control group was 64.4±9.2 IU/L while the patients showed elevated CK values (1081.5 ± 362.9 IU/L) which was significantly higher than the control group ($P<0.0005$).

Conventional electromyogram. In the m. biceps brachii, the mean duration of the MUPs was 5.36±0.7 msec, a time that is significantly shorter (P<0.05) than 8.73±1.05 msec of the control group. For m. tibialis anterior the mean duration was 5.97±1.52 msec which is significantly reduced (P<0.05) as compared to 11.1±1.02 msec of the control group. The mean duration was reduced in 25 and 29 out of the 32 DMD patients in the m. biceps brachii and m. tibialis anterior.

The averaged MUPs amplitude was reduced significantly (P<0.05) in the m. biceps brachii of the patients (777.21±179.4 uV) as compared to 969.63± 122.08 uV of the control group. Likewise, in the m. tibialis anterior it was equal to 796.97±151.95 uV which is significantly reduced (P<0.05) than 1129.5± 97.39 uV of the control group. The results were summarized in Table 1.

An increased incidence of polyphasic potentials of short duration and low amplitude was found in 59% of the DMD patients in the m. biceps brachii and 69.5% m. in the tibialis anterior. Decreased amplitude of the recruited pattern during full effort was found in 15 patients.

In DMD patients, the MPF of the m. biceps brachii was 246.14±30.82 Hz that is significantly higher (P<0.0001) than 180.34±12.57 Hz of the control group. From m. anterior, MPF was also increased significantly (P<0.0005) in the patient group (308.55 ±52.19 Hz) versus 184.66±9.79 Hz in the control. Higher MPF was found in 29 and 32 out of 32 DMD patients in the m. biceps brachii and m. tibialis anterior. DMD patients showed significantly higher (P<0.0005) ppm of the total power values (932.98± 143.8) than 180.11±12.01 of the control group when testing m. biceps brachii. The same significant higher (P<0.0005) ppm of the total power values (1003.72±166.39) was found in the patient group as compared to 208.6±17.71 of the control group when testing the m. tibialis anterior. All patients (100%) showed higher values of the ppm of the total power. The accumulated power was significantly reduced (P<0.0005) in the patient group (96.29±2.49%; 98.88 ±0.31%) in the m. biceps brachii and m. tibialis anterior than that of the control group (99.64± 0.33%; 99.09±1.83%). Lower accumulated power values were found in 85% and 100% of the patients when testing the two muscles. Table 2 illustrates the data of the two groups.

Histochemical examination of the biopsy specimen from the m. quadriceps femoris of DMD patient showed extensive endomysial connective tissue proliferation, loss fibers, variation in the diameter of the muscles fibers, hyaline fibers splitting fibers.

Discussion.

In clinical electrodiagnosis, previous attempts to analyze the pattern of activity on voluntary effort have been directed towards the examination of 20 or more MUP elicited by weak effort. But such a method does not yet appear to have superiority EMG analysis.[7,11]

Conventional electromyogram. Typical short duration, low amplitude MUPs reflecting the MU disorganization[17] was noticed in the DMD patients. The short duration MUPs indicates a marked loss of muscle fibers per motor unit.[18,19] The muscle fiber loss has been supported histologically in our study and in the previous studies.[20] While the muscle fiber loss plus the small size of the regenerating and splitting fibers explains the low amplitude MUPs.

An increased variability of the muscle fiber diameter due to recurring cycles of degeneration and regeneration in DMD, the increase in the variability of the action potential propagation velocity as well as the dispersed course of the nerve sprouts during reinnervation of regenerating and splitting muscle fibers, all leads to a dispersion of the muscle fiber action potential and eventually a new MUP with complex waveform.[21,22]

Power spectrum analysis. A clear shift of the spectrum to the higher frequencies was noticed in the patients group, a finding that all our patients have in common. This finding corroborates the results of other authors.[6,7,9,11,12,20] In a muscle disease, due to the gradual loss of considerable number of muscle

Table 1 - Power spectral analysis of the control group and DMD patients in the biceps brachii.

Group	MPF (Hz)	ppm of the total power	Accumulated power
Control	180.34±12.57	180.11±12.57	99.64±0.33
DMD	246.14±30.82*	932.98±143.8**	96.29±2.49**

*P<0.0001 **P<0.0005
DMD: Duchenne Muscular Dystrophy
MPF: Mean Power Frequency
ppm: part per million

Table 2 - Power spectral analysis of the control group and DMD patients in the tibialis brachii.

Group	MPF (Hz)	ppm of the total power	Accumulated power
Control	184.66±9.79	208.6±17.71	99.64±0.33
DMD	308.55±52.19*	1003.75±166.39*	99.09±1.83*

*P<0.0005
DMD: Duchenne Muscular Dystrophy
MPF: Mean Power Frequency
ppm: part per million

fibers during the course of the illness, it is obligatory for the weakened muscle to activate more motor units and to increase their firing frequency in order to exert the same forces as in normal one.[3] This may explain the shift of the spectrum to the higher frequencies.[23] Moreover, the activated motor units may include many polyphasic potentials of short duration, which are seen on conventional EMG. Thus the chance of overlapping between their action potentials is decrease. Eventually, less cancellation of spike results and that add to a more shift of the spectrum moved towards high frequencies.[4,15,24]

The resulted decrease in the accumulated power is the net result of gradual and persistent muscle fiber necrosis[2] and inadequate regeneration[25] with eventual decrease in the power. In the same direction, a significant increase in the values of ppm of the total power was observed in the patients. This could be explained by the serve loss of muscle fibers leading to reduce motor unit territory.[20] Thus, the developed tension correspondingly reduced.[2] Accordingly, the remaining functional units will perform a given force which is previously carried out by many functional units. In other words, their share in performing a given tension is much higher than normal.

Comparison of the power spectrum analysis and conventional electromyogram. Conventional EMG in its various parameters identified about 74% of the cases. From our results we noticed that the short duration MUPs were found only in 84% of the patients. Low amplitude MUPs identified only 65% of the DMD patients and the polyphasic potentials are found in 64% of the cases. In respect to the power spectrum 95% of the patients were identified. MPF identified about 95% of the patients, 100%, 92.5% of the patients were identified by ppm of the total power and the accumulated power.

These findings indicates that power spectrum is the best in diagnosing DMD patients than the conventional EMG and the best diagnostic yield was obtained by the ppm of the total power. This means that power spectrum analysis indicates myopathic EMG changes in some patients who have normal MUP parameters.

The data of our study represent a new observation since the previous reports found if not equal, less superiority of power spectrum analysis in regard to the manual measurement of individual MUP parameters.[8,9,11,13] This could be explained by that those authors either used analogue filters with poor resolution or surface electrodes or because they examined less number of patients with a wide range of age and different types of myopathies.

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