Shoulder abduction fatiguability

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SUMMARY Shoulder abduction fatiguability has been measured using a hand held myometer in normal subjects and patients with peripheral neuromuscular diseases. An index of fatiguability was based on the decline in force over a series of ten maximum voluntary contractions performed in under a minute. The technique was repeatable and well tolerated. Patients with myasthenia, mitochondrial myopathy and motor neuron disease tended to show excess fatiguability independent of muscle strength. Serial measurements demonstrated alterations in fatiguability but not necessarily strength, associated with changes in symptoms.

Fatiguability is a common symptom in peripheral neuromuscular disease. Commonly the clinician assesses this subjectively by repetitive manual “breaking” of shoulder abduction or some other muscle group. However, this is difficult to quantify and compare from examination to examination. More elaborate techniques utilising electrically stimulated muscle contractions¹ or isokinetic dynamometry² have been used, particularly for assessing knee extension, but generally require complex apparatus and are impractical for routine use.

In this study we define fatiguability as the reduction in muscle contraction force with repeated maximum efforts. We have developed a simple technique to quantify fatiguability, which can be employed in the clinic; the percentage decline in shoulder abduction force over ten successive maximum voluntary contractions (MVC), is measured using a hand held dynamometer.

A preliminary report of this work was made at the Association of British Neurologists’ Meeting, Belfast, April 1986.

Methods

(A) Technique

The subject is seated, the back unsupported, with the non-dominant arm to be assessed abducted to 90°, the elbow flexed to 90° and the forearm pronated (fig. 1). In the small number of patients where shoulder abduction strength was less than MRC³ grade 3, the fatiguability test was conducted

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Fig 1 Positioning of operator and subject for the fatiguability test.

with the patient in supine position. The method and necessity to maintain the arm position throughout the test is explained carefully to the subject. A hand held dynamometer (Penny and Giles Ltd., Airfield Road, Christchurch, Dorset), is positioned by the examiner just proximal to the lateral epicondyle of the humerus,⁴ and sufficient

Table Weakness and fatigability in peripheral neuromuscular diseases

Diagnosis	Total	Weak No. (%)	Fatiguable No. (%)	Both No. (%)
Myasthenia gravis	16	10 (62.4)	14 (87.5)	10 (62.5)
Congenital myasthenia	9	8 (88.8)	9 (100)	8 (88.8)
Lambert Eaton Syndrome	11	5 (45.4)	7 (63.5)	3 (27.3)
Mitochondrial myopathy	10	6 (60)	4 (40)	3 (30)
Other myopathies	28	14 (50)	4 (14.2)	3 (10.7)
Muscular dystrophy	8	8 (100)	1 (12.5)	1 (12.5)
Neuropathy	19	13 (68.4)	4 (21.1)*	3 (15.8)*
Motor neuron disease	9	5 (56)	4 (45)	3 (33)
Unknown	5	3 (62.8)	0 (0)	0 (0)
Total	115	72 (62.6)	47 (40.8)	34 (29.5)

*Guillain-Barré syndrome.

counterforce applied to just overcome the subject's maximum effort: the peak force is registered by the dynamometer. The subject is then required to make a series of ten maximum contractions over a total of 50–55 seconds, with approximately two seconds rest between each contraction.

A Fatigue Index (FI) is calculated as the difference between the mean of the first two and last two contractions, expressed as a percentage of the mean of the first two; that is

$$\frac{F_{1,2} - F_{9,10}}{F_{1,2}} \times 100\%$$

The possibility that failure to maintain the starting position would influence MVC and hence FI was investigated in a sample of 21 normal subjects (11 females, 10 males). Each was asked to produce three MVCs first at 90° and then at 60° of shoulder abduction. This sequence was then reversed in a second series to eliminate the effects of order. The same technique was applied to compare 90° and 60° of flexion in abduction.

Inter-observer variability was also examined in a sample of 11 patients with diverse neuromuscular diseases. The FI was measured twice within four hours on the same patient, by two examiners independently.

(B) Subjects and patients

Normal values were obtained in 50 control subjects, 25 females (aged 20–65, median 30 years), and 25 males (aged 20–60, median 34 years).

The test was incorporated at the end of our routine assessment of patients with peripheral neuromuscular disorders which includes myometry,⁴ performance test,⁵ and a visual analogue score of symptomatic state.

Results from 115 consecutive patients with a variety of neuromuscular diseases are reported in this paper (see table). Only patients with a definite diagnosis were included, apart from a small group whose main clinical features were non-specific "weakness and fatigue". The results included are the first FI measurement made in each patient regardless of treatment status. For each patient the values of the 10 force measurements were plotted onto a standard graph of the normal values for sex and were classified as "weak" and/or "fatiguable" by an observer who was unaware of the diagnosis. In a number of patients we have also made serial measurements of FI during the course of their treatment.

Fig 2 (a) Normal range of mean shoulder abduction strength in 25 females ($\pm 2SD$). Force increased from the first to the second contraction and then declined. (b) Normal range of mean shoulder abduction strength in 25 males ($\pm 2SD$). Force declined from the first to the fifth contraction then remained constant.

Results

(a) Normal subjects (fig 2A, B)

Mean shoulder abduction strength (mean of the first two measurements) in females was 150N (range 97–203N, $\pm 2SD$) and in males it was 227N (range 149–305N, $\pm 2SD$). Strength declined slightly with age in men ($r = 0.47$, $p = < 0.02$), but not in women ($r = 0.29$, $p = < 0.1$). In both sexes the fatigability index (FI) had a normal distribution of values. The mean in females was 6.1% (range -6.7 to $+19.4\%$, $\pm 2SD$) and in males 6.1% (range -7.3 to $+19.4\%$, $\pm 2SD$); the mean values for males and females were not significantly different ($p > 0.1$) and the combined values for both sexes was -6.8 to $+19.0\%$ (mean 6.1%). Thus a few subjects showed a slight increase in force (negative values) over 10 contractions. No correlation was found between FI and strength ($p = > 0.1$).

As mentioned in *Methods*, the effect of deviations from the starting position was examined. There was found to be no significant difference ($p = 0.4$)

Shoulder abduction fatigability

between MVCs at 90° and 60° of abduction, or MVCs at 90° and 60° of forward flexion in abduction. Therefore it seems unlikely that any failure to maintain the starting position would account for an increase in fatigability index. Inter-observer variation was low; the correlation coefficient between FI measured by two examiners in 11 patients was 0.96 ($p < 0.01$).

(b) Patients (table)

Patients classified as fatigable all had a Fatigue Index (FI) $> 20\%$; those whose initial strength (mean of first two contractions) was more than 2SD below the normal mean for sex were considered weak. In many of those with myasthenia, fatigability was very abnormal; one third had an FI of more than 50%. Of the fatigable myasthenic group, 70% were weak, but in 30% strength fell within the normal range. There was no statistically significant correlation between weakness and fatigability in patients with myasthenia gravis or congenita. In the group with Lambert Eaton Syndrome there was a tendency for the FI to increase (that is, more fatigable) with increasing strength but this did not reach conventional statistical significance ($r = 0.52$, $p = 0.08$, $n = 11$). Within the mitochondrial myopathy group, 40% had a significant FI (ie $> 20\%$); however, the mean for the whole group was 18.3%, considerably higher than the combined mean for normal males and females (mean = 6.1%). The four patients with neuropathy who showed excess fatigability, all had Guillain-Barré syndrome, but none had a major degree of sensory loss. Four other patients with Guillain-Barré syndrome had normal FIs.

Serial measurements in some patients yielded clinically useful data. Several cases have been looked at over a period of time, ranging from four weeks to four months:

Fig 3 Case 1. Female patient, aged 61 years with neurosarcoidosis. Serial measurements were made during treatment with prednisolone.

Fig 4 Case 2. Female patient, aged 29 years with myasthenia gravis. Serial measurements of walking time over 30 metres, shoulder abduction strength (N), visual analogue scale of symptoms, and FI are shown.

Case History 1. (fig 3)

A female patient, aged 61 years with neurosarcoidosis and proximal weakness, was treated with prednisolone. Shoulder abduction strength, and that of other muscle groups recorded, only improved slightly. However, the FI declined markedly (that is, reduced fatigability), in parallel with a striking improvement in her general symptoms.

Case History 2. (fig 4)

A 29 year old female patient with myasthenia gravis

Fig 5 Case 3. Male, aged 25 years with Guillain-Barré syndrome. Both FI and timed walking could not be measured until 30 days post onset.

was admitted for a course of plasma exchange. In the following three weeks, muscle strength changed minimally but her fatiguability index improved as did her timed walking and symptomatic state.

Case History 3. (fig 5)

A male, age 25 years with Guillain-Barré syndrome, was followed up over four months. In contrast to the other two cases, muscle strength improved greatly but the FI still remained high. Late improvement in fatiguability may account for the prolonged period required to return to premorbid fitness.

Discussion

The term "muscle fatigue" has been used to refer to a variety of phenomena associated with prolonged or repeated contractions. These include a decline in force,⁶ selective force loss at high⁷ or low frequencies⁸ of electrical stimulation, slowing of contractile properties⁹ and changes in the EMG power spectrum¹⁰ and muscle fibre conduction velocity.¹¹ By using the term fatiguability, we refer to the clinically apparent reduction in maximum voluntary strength with repeated contractions. The technique described has allowed us to express such fatiguability in a reproducible, quantifiable manner, helpful in monitoring patients.

There are some difficulties inherent in the test. We noted that some subjects did not sustain concentration throughout the test and it is therefore important to achieve cooperation between operator and patient and maintain effective verbal encouragement at all times to produce their best efforts especially in the latter half of the test. Afferent influences, notably pain but also input from the joint capsule, may inhibit production of an MVC.¹² In some patients with mitochondrial myopathy we had the impression that the initial contraction was somewhat tentative: a failure to make a full initial effort would tend to lead to an apparently low fatiguability index.

Significant fatiguability could be demonstrated in 83% of the myasthenic patients even though these patients were all on treatment though not in full clinical remission. In line with clinical impressions 40% of the patients with mitochondrial myopathy were fatiguable.

Other groups rarely showed fatigue (as defined by our test), except for two groups: these were patients with Guillain-Barré syndrome and motor neuron disease. Our sample size for these groups is small, but their fatiguability is an area we would like to investigate further. Within the motor neuron disease group, it has been our impression that there are two sub-groups: those who fatigue severely, that is, four

patients with a mean FI of 47% (range 21.7 to 66.3%) and those who do not fatigue, five patients with a mean FI of 8.2% (range -1.6 to 17.5%). Three of the fatiguable patients were also weak as were two of the non-fatiguable patients. None of the undiagnosed group with non-specific "weakness and fatigue" were shown to have significant fatiguability (mean FI 7.6%, range 1 to 14.4%, $n = 5$) despite 60% being weak.

Although it might be expected that pathological physiological processes leading to fatiguability and weakness would be similar, we find that in our population of patients there is no simple correlation. This is confirmed in the limited serial data on treated patients which demonstrates that strength and fatiguability in individual muscle groups may vary independently. We are now collecting more serial data on patients with a view to investigating this more closely.

Few tests of fatiguability applicable to patients have been described in the literature. Test of timed performance¹³ in which the time that the head or leg can be held in a standard position have been used, but seem to be more dependent on the patient's motivation and, in our hands produce rather variable results. In one study¹⁴ these tests were found to discriminate between diseased and normal muscle, but were an insensitive means of monitoring progress.

Many authors have previously emphasised the value of serial strength measurements in monitoring patients with peripheral neuromuscular diseases;⁴ nevertheless, we are aware that a few patients complain more of fatiguability than weakness. The fatiguability index can be used to document excessive fatiguability in shoulder abduction but it should not be assumed that FI will be similar in other muscle groups. Serial measurements may indicate changes in clinical state which are not obvious from examination in simple strength measurements, but which the patient finds significant. The test appears robust, easy to perform and reliable, but as with all such tests, should be interpreted in conjunction with changes in symptoms, clinical performance and strength.

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