INVESTIGATION OF THE CATCH PHENOMENON WITH APPLICATION TO FES

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ABSTRACT

The catch phenomenon whereby a high frequency pulse doublet at the beginning of a low frequency pulse train results in an enhanced tension output and an improved rise time is investigated for human quadriceps muscle. Results are presented for frequencies in the range 6 to 20 Hz showing improvement in tension and rise time, being particularly marked at the lower frequencies. This phenomenon may be of use in FES systems where a high frequency pulse train would cause conduction fatigue.

INTRODUCTION

The catch property in single motor units of cat triceps surae was reported by Burke et al (1970). A patterned stimulation sequence with one inter-pulse interval much shorter than the others resulted in a significant tension enhancement within a certain range of stimulation frequencies.

This phenomenon is of particular interest for functional electrical stimulation (FES) systems for restoration of gait in paraplegics where sustained high stimulation frequencies are to be avoided because of rapid conduction fatigue (Kralj et al, 1980) but where a fast response time at a high tension level may be required.

METHOD

The following protocol was observed for investigation of human quadriceps muscle: normal subjects sat in a chair with one leg supported at 60 of flexion whilst isometric knee extension forces were measured. Quadriceps was stimulated at its motor point with large surface electrodes. Pulses of 300μs duration were delivered at the maximum comfortable level (50-80 mA). A laboratory computer generated patterned stimulation sequences with the first inter-pulse interval being 10 ms (a doublet) and the following frequency being 6-20 Hz, these tests were also performed without the doublet for comparison. Data was sampled at 400 Hz via a 12 bit A/D convertor on a Compaq PC.

RESULTS

Two significant features were noted:

(1) the catch phenomenon was observed with an enhanced tension output lasting 250 ms. Tension enhancement was particularly marked at the lower stimulation frequencies although with a shorter duration than observed by Burke et al on the Type S unit.

(2) a shorter rise-time of the force output. To compare the effect on rise time, the maximum rate of change of force output was calculated with and without the doublet and the ratio of the two determined. Table 1 gives illustrative results from one subject:

Frequency (Hz)	Ratio: doublet/normal
6	2.67
8	1.83
10	1.74
12	1.59
15	1.41
20	1.21

Table 1 Rise time improvement

Figure 1 shows the response obtained at 6, 12 and 20 Hz.

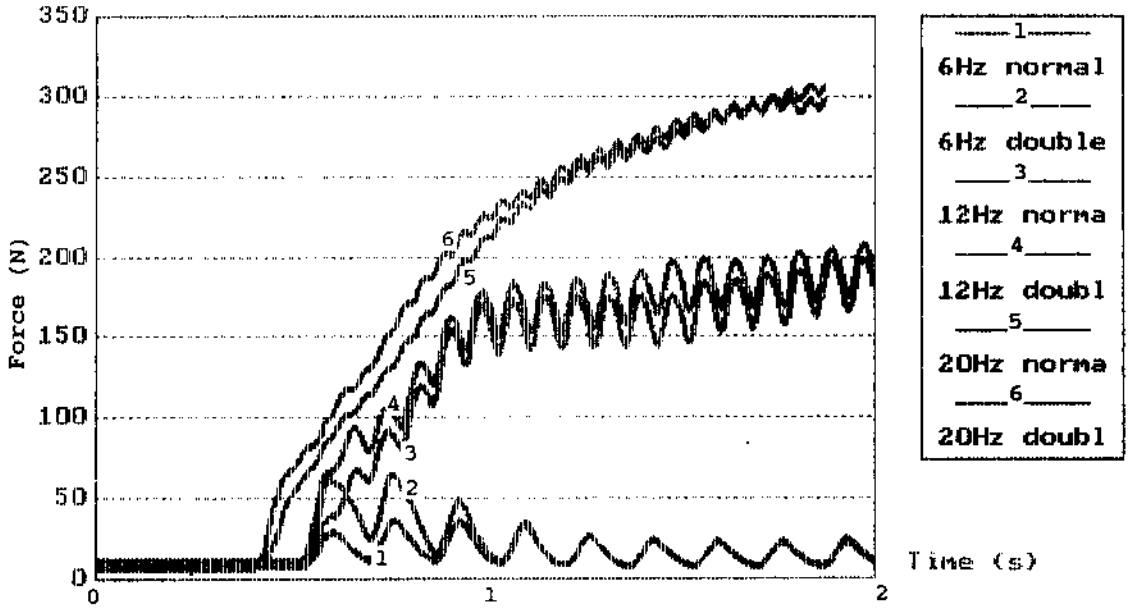

Figure 1 Force output against time with and without doublet at base frequencies of 6, 12 and 20 Hz (note 20 Hz time scale shifted for ease of viewing).

DISCUSSION

The results in table 1 show that the improvement in rate of tension development varies inversely with stimulation frequency. That is, as the base frequency increases the rise time produced more closely approximates that obtained from the high frequency pulse.

From figure 1 it can be seen that the tension enhancement is also greater at lower, sub-tetanic, frequencies.

CONCLUSION

The catch phenomenon has been observed in human quadriceps muscle and this may be of use for FES systems where a fast, strong initial response would be required with minimum fatigue.

REFERENCES

Burke RE, Rudomin P, Zajac FE (1970), Catch Property in Single Mammalian Motor Units, Science, 168, 122-124

Kralj A, Bajd T, Turk R (1980), Electrical Stimulation Providing Functional Use of Paraplegic Patient Muscle. Med Prog Technol, 7, 3

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