RELATIONSHIP BETWEEN MUSCLE FORCE, LENGTH AND MYO-ELECTRIC ACTIVITY IN VIVO

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ABSTRACT

A vast amount of physiological data exists for the mechanical and electrical behaviour of voluntary skeletal muscles. The data, however, are almost exclusively obtained under conditions of artificial stimulation and also are usually only concerned with the static properties of the muscle.

This paper presents an experimental procedure aimed at the development of a dynamic model relating the tendon force output of the muscle to its myo-electric activity. Transducers for the measurement of the muscle force and length in vivo are described as well as the electrodes used to measure the myo-electric activity.

The determination of the experimental model is guided by a theoretical model. The theoretical model uses the motor unit as a basic block with the neural signal to the muscle as an input. The theoretical model indicates that a suitable system between the myo-electric signal and force is that of an instantaneous nonlinearity followed by a linear system. To this end a modification of a known modelling technique is used.

EXPERIMENTAL PROCEDURE

The experimental animals used are sheep. Electrodes made of 6-0 suture wire attached to teflon coated hook-up wire are inserted in the peroneous longus muscle. The electrode's ends are barbed and they are spaced 0.5 inches apart in a plane parallel to the muscle fibers. On the muscle's tendon is placed the force transducer (Figure 1A) which operates on a tensiometer type principle. The transducer is easy to install and does not require severing of the tendon. Though the primary aim is to relate tendon force to the myo-electric signal, the literature (1) indicates that the force is strongly dependent on the muscle's length and velocity of shortening. Therefore a length transducer (Figure 1B) has been developed and is currently being evaluated.

The electrodes, force and length transducers are implanted in a sheep with wires leading out through the skin at an appropriate place. Tests are then conducted four days later. This time period is felt to be sufficient for the sheep to recover from the surgery while at the same time the formation of scar tissue is not too severe.

THEORETICAL MODEL

As an aid in the interpretation of the experimental data the muscle has been modelled as shown in Figure 2. The motor unit is considered as a basic unit and has been modelled as a force generator which drives a parallel viscous element and a series elastic element (2). Each force generator is controlled by a neuronal spike train which are considered to be a series of impulses. This neuronal spike train also gives rise to the myo-electric signal picked up by the electrodes. Considering that all the motor units are identical and that there are m of them, a second order differential equation relates the tendon force, F(t), to the motor unit's force generator, $f_i(t)$. However in the experimental model it is the myo-electric signal which is considered to be the input not the force, $f_i(t)$. The measured myo-electric signal of a single unit is biphasic while the force, $f_i(t)$, is unidirectional. Thus the model between the myo-electric signal and the force is postulated to be that of an instantaneous even nonlinearity followed by a linear system.

A method for modelling systems of this form has been presented (3). At present the method has been tried out on a simulated model and is now being applied to the experimental data.

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REFERENCES

(1) Wilkie, D. R., "The Relation Between Force and Velocity in Human Muscle"; The Journal of Physiology, Volume 110, 1949, pp. 249-280.

(2) Bahler, Alan S., "Modeling of Mammalian Skeletal Muscle"; IEEE Transactions on Bio-Medical Engineering, BME-15, No. 4, Oct., 1968, pp 249-257.

(3) Glukhov, A.B., "Recovery of a Nonlinear Link's Characteristics From its Input and Output Signals"; Automation and Remote Control, No. 11, pp. 82-90, Nov. 1967.

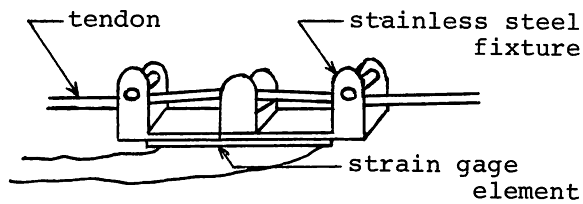

FIGURE 1A - FORCE TRANSDUCER

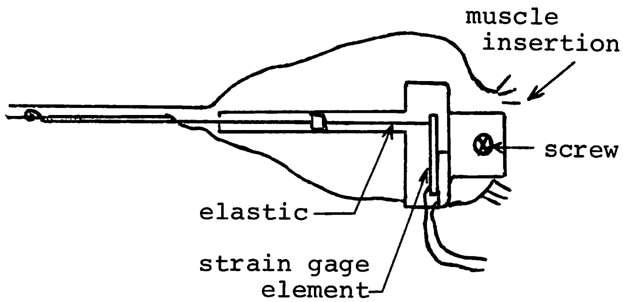

FIGURE 1B - LENGTH TRANSDUCER

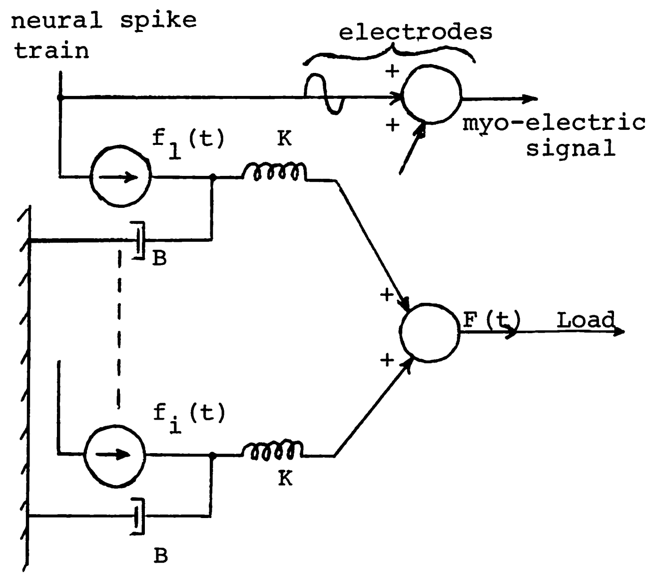

FIGURE 2