AN ELECTROMYOGRAPHIC TECHNIQUE FOR COMPARING THE RELATIVE INVOLVEMENT OF SKELETAL MUSCLES DURING EXERCISE

G. B. Thompson

Research Associate, Bio-Engineering Inst. & Associate Professor of Physical Education

University of New Brunswick, Fredericton, N.B.

ABSTRACT

One fundamental limitation in the exercise specialist's ability to prescribe the most effective conditioning or rehabilitation exercise for a particular individual is his understanding of the exact muscular demands of each exercise. Researchers interested in conditioning and therapeutic exercises have found the myo-electric signal a useful diagnostic tool for determining phasic action, and for subjectively assessing the tension levels of participating muscles. It is now generally accepted that the electrical activity in human skeletal muscle bears a linear relation to the tension being exerted during an isometric contraction when experimental conditions are strictly standardized. This relationship also applies to a muscle shortening at a constant velocity.

Despite the obvious advantages in knowing the quantitative involvement of specific skeletal muscles in various exercises, most of the research has been confined to subjective assessment of action potentials. On the basis that the integrated myo-electric signal can be displayed as a deviation from the baseline proportional to the strength and duration of muscle contraction, a technique was developed in an attempt to permit a comparison of the quantitative involvement of a specific muscle for various exercises.

This paper describes the instrumentation and technique employed as well as some initial observations obtained when six shoulder and arm muscles of 40 subjects were compared for ten different variations of the shoulder flexion - elbow extension movement.

APPROACH

Recognizing that the linear relationship between muscle tension and electrical activity are known to be individual and dependent upon the muscles studied, we decided to base any quantitative measure of the degree of involvement of a given muscle in a given exercise as a percentage of that muscle's "maximum" isometric contraction. Our approach is based on the work of Hill [7], and of Bigland and Lippold, [6], which suggests that the myo-electric signal is proportional to the isometric tension and that, for any given load, F, at a given velocity, the resulting signal is a measure of an equivalent isometric contraction of tension F_o.

The "pushup" exercise involving elbow extension and shoulder flexion was arbitrarily chosen for initial investigation. The triceps brochii, anterior deltoid pectoralis major (clavicular and sternal portions) and the forearm extensor muscles were selected for monitoring.

Activity of the rectus abdominus was included in an attempt to assess the degree of trunk stabilization associated with each of the ten movements. Phasic activity for all six muscles was also recorded.

To obtain a myo-electric signal which represented the "maximum" force output of the muscle the cable-tension strength test techniques developed by Clarke and associates, [1], were used. Maximum static contractions of shoulder flexion, elbow extension, wrist dorsal flexion were obtained for this purpose.

The integrated myo-electric signal of each muscle was then recorded for each of the selected exercise variations.

Because a linear relationship between muscle tension and electrical activity exists only where there is constant velocity of muscle contraction, [8], all movement during execution of these exercises was controlled by training the subject to move through the full range of movement of the exercise at a constant velocity.

The portion of the record of a specific muscle's output during exercise which was selected for comparison with that during maximum output was that portion of the total signal representative of the largest amount of effort under conditions of constant velocity.

INSTRUMENTATION AND SIGNAL PROCESSING

Instrumentation for both signal display and absolute mean level measurement was required.

Myo-electric signal data was obtained by the use of a seven channel recording system including Beckman surface electrodes, TEKTRONIX 125 pre-amplifiers, buffer amplifiers, magnetic tape recorders (for signal storing) and a Hewlett-Packard 7200 eight channel heat-writing recorder. Six channels recorded the myo-electric activity while the seventh was used to record the timing device and thereby link the arm position and angles of elbow and shoulder to the integrated signal during the exercise.

For measurement of the absolute mean level of the myo-electric signal a six-channel integrator system was used consisting of a low level full wave rectifier followed by an operational amplifier integrator. The period of integration, controlled by a multivibrator, was set to 0.1 seconds.

OBSERVATIONS

On the basis of our work to date, it appears that, under carefully controlled conditions, the integrated myo-electric signal obtained from a muscle during an isotonic contraction of constant velocity, can be given a quantitative value by being represented as a percentage of a determined "maximum" obtained by static contraction.

Statistical analysis employing the t test showed significant differences - in many cases to the .01 level - between mean levels of each muscle for the 10 variations of the pushup exercise. No one variation required maximum demands for all muscles involved.

ACKNOWLEDGEMENTS

The work was supported primarily by the Fitness and Amateur Sport Directorate of the Department of National Health and Welfare.

REFERENCES

1. Clarke, H. H., "A Manual of Cable-Tension Strength Tests," Springfield College, Springfield, Mass.; 1953.
2. Bergstrom, R. M., "The Relation Between the Integrated Kinetic Energy and the Number of Action Potentials in the Electromyogram During Voluntary Muscle Contraction," Suomalainen Tiedeakatemia, Helsingfors, Medica, SA, Vol. 93, pp. 3-24; 1962.
3. Close, J. R., Nickel, E. E., and Todd, F. N., "Motor Unit Action Potential-Counts, Their Significance in Isometric and Isotonic Contractions," J. Bone & Joint Surgery, Vol. 42A, pp. 1207-1222; October, 1960.
4. Inman, V. T., et al, "Relation of Human Electromyogram to Muscle Tension," Prosthetic Devices Research Project, Institute of Engineering Research, University of California, Berkeley, Issue 18 of Series 11; 1951.
5. Lippold, O. C. J., "The Relation Between Integrated Action Potentials in a Human Muscle and its Isometric Tension," J. Physiol., Vol. 117, pp. 492-499; 1952.
6. Bigland, Brenda and Lippold, O. C. J., "The Relation Between Force, Velocity and Integrated Electrical Activity in Human Muscles," Journal of Physiology, Vol. 123, pp 214-224; 1954.
7. Hill, A. V., "The Heat of Shortening and the Dynamic Constants of Muscle," Proc. Roy. Society B, pp. 156-195; 1938.
8. Jonsson, B. and Reichmann, S., "Reproducibility in Kinesiologic EMG Investigations with Intramuscular Electrodes," Acta Morphologica Neerlando-Scandanavica, Vol. 7, pp. 73-90; 1968.