THE ELECTRICAL RESPONSE OF HUMAN SKELETAL MUSCLE TO PASSIVE STRETCH*

ROBERT O. BECKER

The tone of the skeletal musculature is routinely evaluated by the clinician in diseases of the neuromuscular system, but to date the physiologists have not been able to find any evidence for the existence of such muscle tone in the human being. Since Ranvier[5] first described the difference between red and white muscle there has been considerable controversy over the possibility of a completely separate automatic neuromuscular system controlling muscle tone in relation to posture. The major findings, however, have been negative and at present the concept of the final common path utilizing the muscle fibers of all or none characteristics is the accepted one. The comparative physiologists for some time have demonstrated that the dual system is predominant in the lower phyla (Hoyle).[3] In 1953 Kutner[4] first demonstrated two types of muscle fibers in the frog, one following the accepted all or none law, the other being variable in response and incapable of developing a propagated impulse. More recently Granit[1,2] has demonstrated appropriate anterior horn cell groupings for such a system in the cat and has elucidated the dependence of the tonic system upon the gamma circuit (muscle spindles, and control centers in the reticular formation, cerebellum, etc.).

If such a dual system existed in man then disturbances in function of any function of the tonic system should produce a variety of clinical conditions and at the same time should be amenable to surgical intervention without compromising the activity of the voluntary system. Since only the skeletal muscles are readily available for study in man, a series of electromyographic criteria can be established (assuming a system analogous to that in other vertebrates) for the existence of a tonic muscle fiber system.

1. The activity of the tonic fibers should be distinguishable electronically from that of the voluntary fibers.
2. This activity should be found in greater abundance in postural muscles in comparison to non-postural muscles.
3. The activity should be produced by passive stretch of the muscle and should bear a definite relationship to the cycle of stretching.
4. Potentiation of the activity should occur with repeated stretch cycles.

In a preliminary survey of 28 subjects it is felt that these criteria are sufficiently fulfilled to indicate the existence of a dual neuromuscular system.

METHOD

Electromyography was done using coaxial needle electrodes, a wide band D.C. preamplifier and a dual beam D.C. oscilloscope. The noise level of the equipment measured 20 microvolts. Recordings were made photographically with an oscillographic camera at a film transport speed of 600"/min. Magnetic tape recordings were made simultaneously on a wide band frequency modulated tape recorder. The tapes were later monitored and 4.6 sec. segments of the desired activity were used as playback loops for frequency analysis using a continuously tunable frequency analyzer to determine the frequency spec-

* State University of New York, Upstate Medical Center, Syracuse, N. Y. Supported by Veterans Administration Hospital, Syracuse, N. Y.

Reprint from Vol. X, "Surgical Forum," 1960

trum components of the various types of activity. The muscles evaluated were passively stretched through a normal range of motion, 10 times with each stretch cycle averaging 5 seconds. Recordings of voluntary activity and stretch responses were made from the same site in each muscle. The gastronemius, soleus, anterior tibial, quadriceps and triceps muscles were routinely evaluated.

RESULTS

Of six normal subjects only one demonstrated electrical responses to stretch and that only in the soleus muscles bilaterally. This activity, while clearly distinguishable from voluntary activity, was inconsistent in nature and very low in amplitude averaging about 30 microvolts. In the remainder of the normal subjects no responses were obtained in any of the muscles tested. Since Kuffler[4] reported the magnitude of the tonic fibres impulses in the frog to be about 10 microvolts, it is evident that the normal tonic potentials in man may be below the noise level of the present equipment. In 22 other subjects (including 11 herniated lumbar discs, 2 cervical discs, 6 cases of polymyositis and 3 cases with muscle spasm of obscure etiology clinically compatible with benign myalgic encephalomyopathy) distinctive electrical activity was found on passive stretch of the soleus, quadriceps, and long head of the triceps. The activity was absent or minimal in the anterior tibial, gastrocnemius and long and medial heads of the triceps. These stretch responses were evidently distinct from the electrical activity recorded during voluntary contractions of the same muscle and fell into two general types: Type A consisting of rhythmically repetitive high frequency wave forms with an initial sharp positive flection 100 microvolts or greater in amplitude (Fig. 1, lines B and C) and Type B of random high frequency wave forms of generally positive sign and amplitude of 100 microvolts or less (Fig. 1, lines D and E). Both types of activity appeared in bursts of from 0.05 sec. to 0.1 sec. in duration during the periods of greatest tension charge, i.e., during the last portion of the stretch or the first portion of the release cycle. Most often the two types of response were mixed in the same patient; occasionally one or the other would predominate. Some recordings suggest the transition from one type to another. In all cases both types of activity were potentiated in amplitude, frequency of repetition and total duration by repeated stretching (Fig. 1, lines B, C, D, E). In the cases of polymyositis these muscles appeared to be particularly irritable and only minimal stretch was required to produce long chains of oscillations. These were interesting in that occasionally each succeeding wave form would show a standard decrement in amplitude and would occur at a slightly reduced interval of time. The similarity with a oscillatory condensor discharge is obvious. Assuming the individual wave forms to be from the same fiber the deviation from all or none behavior was evident. Additionally, these cases, as well as those with the possible benign epidemic myalgia, would show spontaneous bursts of high frequency activity following or during maximum voluntary contraction (Fig. 1, line F) or movement of the coaxial needle. These were identical to those recorded during stretch. The disc lesions selected for the study were those with minimal physical signs. In all subjects typical stretch responses were obtained from the soleus muscle on the affected side regardless of the level of disc protrusion. In 3 of the cases myelogram was negative; nevertheless, subsequent laminectomy revealed a degenerated disc and attenuated root at either L4-5 or L5-Sl and typical clinical improvement followed disc

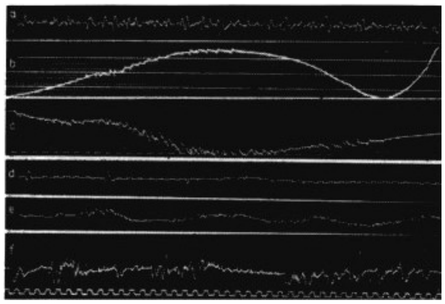

Fig. 1. A—Normal voluntary action potentials recorded from soleus muscle.
B.—Type A stretch responses, third stretch.
C.—Type A responses from sixth stretch, same patient as A and B, note potentiation.
D.—Type B responses to first stretch.
E.—Type B responses to tenth stretch, same patient as D. Again note potentiation.
F.—Type B responses occurring in the first group of action potentials recorded during beginning of voluntary activity following ten stretches.

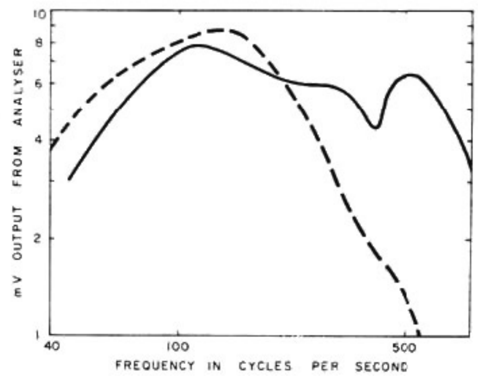

Fig. 2. Frequency spectrum of voluntary activity (dashed line) and stretch responses (solid line). The shift towards a higher spectrum in the case of the stretch responses is evident.

removal. In the remainder of the disc cases myelography was positive and disc lesions were proved at surgery. It is suggested that the stretch response may be a more sensitive index of disc disease than either fibrillation or fasciculation which are late signs occurring when the diagnosis is clinically evident.

In the 22 subjects with positive stretch responses, frequency analysis of both voluntary activity and the stretch responses (either Type A or B) was made. In all cases the frequency spectrum was markedly different in the stretch responses compared to that of voluntary activity. Consistently there was a shift in the major components towards the high frequency ranges with sharp peaks in the 500-600 c.p.s. range (Fig. 2).

SUMMARY AND CONCLUSION

The criteria for a tonic muscle fiber system in man have been fulfilled in that distinctive electrical responses to passive stretch have been found in the postural muscles of patients with clinical syndromes characterized by an increased irritability of the skeletal musculature. Electronic analysis indicates a basic difference in the mode of production of the wave forms. Since the tonic fiber system does not follow the all or none law, its activity can be potentiated by pathological influences in the tonic fibers themselves or anywhere in the spindle control circuit. This is evidenced clinically by hyperirritability of the involved musculature and electronically by measurable responses to passive stretch.

REFERENCES

1. Cranit. R.: Neuromuscular interaction in postural tone of the cat's isometric soleus muscle. J. Physiol., 1958, *143:*387–402.
2. Cranit, R., Holmgren, B., and Menon, P. A.: Two routes for excitation of muscle and their subservience to the cerebellum. .J. Physiol., 1955, *130:*213–224.
3. Hoyle, C.: Comparative physiology of the nervous control of muscular contraction. Cambridge University Press, l957.
4. Kuffler, S. W.: The two skeletal nerve muscle systems in the frog. Arch. exper. Path. u. Pharmakol., 1953, *220:*116–135.
5. Ranvier, L.: Des muscles rouge et des muscle blancs chez les rongeurs. C. rend. Acad. sc., 1887, 79–80.