The Electrical Response of Human Skeletal Muscle to Passive Stretch

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In a recent series of articles Granit and associates [9] and Eccles and associates described two functional types of anterior horn cells in the cat. These they identified as tonic alpha and phasic alpha types; they considered them to be distinct from the gamma-circuit motoneurons. The activity of the tonic alpha cells is characterized by a sensitivity to passive stretch of the corresponding skeletal muscle with potentiation <f tl.e discharge on repeated stretching. The tonic motoneurons were considered to innervate tonic postural muscles, although to date no evidence for any such division of function in the skeletal muscles of man has been presented. The results reported[6*-910] were based on decerebrate preparations. What the function of the tonic alpha cells and the postulated tonic postural muscles would be in the intact animal was not demonstrated.

The question of duality of the human neuromuscular system has been investigated and debated since Ranvier's observation in 1887 of the slower contraction rate and longer latent period of so-called red muscle as compared with so-called white muscle. It has been evident that the anatomical arrangement of the red muscles and their functional and electrical parameters favor a postural or tonic function, whereas the arrangement and parameters of the white muscles favor a voluntary or phasic function. Such a functional dichotomy, with two parallel anatomical systems, each containing neural and muscular units, was shown to be widespread among the invertebrates[11]. It was not until 1951, when Kuffler demonstrated the presence of slow fibers in the iliofibularis muscle of the frog, that the system was extended into the vertebrates. The work of Granit and associates and Eccles and associates, as just described, has recently revealed evidence for certain types of anterior horn cells in the cat that could form the neural portion of a tonic or postural neuromuscular system in that mammal. If evidence for a dual system in man could be obtained, many perplexing problems would be solved, both from the theoretical and the practical aspect. For example, to the clinician the existence' of muscle tone is as evident as the existence of muscle spasm. Yet the single neuromuscular system does not contain sufficient functional parameters to explain the latter satisfactorily and, in fact, completely denies the existence' of the former. In view of the widespread occurrence of dual neuromuscular systems in other forms of life, it would appear most logical that man would have, at least, the residuals of such an arrangement. In that case, abnormal functioning of any portion of the tonic system could produce the wide variety of clinical syndromes evidenced by postural abnormalities. Since the postural elements of such a system would most certainly have central (cranial) connections different from the voluntary system, they should be amenable to surgical manipulation without altering the function of the voluntary system. Furthermore,

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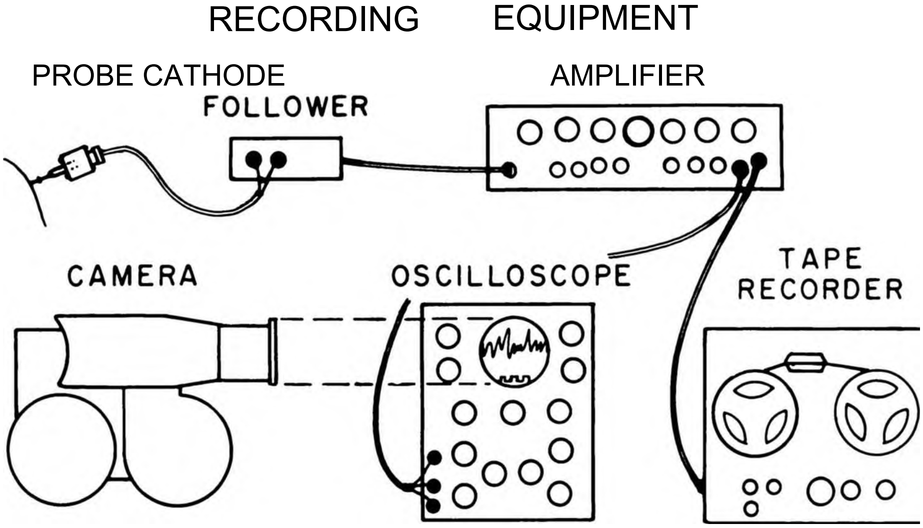
the specialized tonic muscle fibers may have different chemical mediators or have drug sensitivities different from the voluntary system and may therefore be medically influenced in a selective fashion.

Since the neuromuscular disorders remain a considerable problem to the clinician it would be of great interest to determine whether any evidence exists for such a duality of function in the human neuromuscular system. The motoneuron pool in the human being is not readily available for study, but the peripheral musculature is. An evaluation of the skeletal musculature under the conditions shown to produce activity of the tonic motoneurones may demonstrati' activity of an analogous nature. Furthermore, the difference in such activity between normal persons and those with muscular irritability due to disease would be interesting from the therapeutic and diagnostic viewpoints. (Of some importance in clinical experimentation is the fact that an intact preparation is used and decerebration or the like is not required to produce cooperation. Because of this the results in clinical experiments may not necessarily be similar to those obtained in animal experiments.)



Fm. 1

Diagram of the experimental setup for obtaining the electromyograms used in the analysis. This setup is more elaborate than is necessary clinically but represents a method of considerable accuracy. As standardization of technique is becoming important in clinical electromyography, some consideration must be given to the accuracy of each method utilized.

METHODS

A modified coaxial needle electrode was used as the pickup device '.

These electrodes have a small area of signal intercept (the spherical volume of muscle surrounding the tip of the electrode from which action potentials are picked up); they provide complete reproducibility of results from one case to the next; and they have excellent frequency characteristics. Additional instrumentation consisted of a direct-current preamplifier (Grass PG) and a dual-beam oscilloscope (Dumont 322A). Total noise level was measured at twelve microvolts under clinical conditions. The recordings were made with a Dumont 321A oscillographic camera on Kodak Linograph Pan film at a film transfer speed of GOO inches per minute. Simultaneous recordings were made on a frequency modulated tape recorder at a speed of 450 inches per minute. A second oscilloscope was utilized for visual monitoring throughout the entire procedure. The experimental setup is schematically shown in Figure 1.

Wave analysis is a method of electronically breaking down a wave form into its component sine waves. It has been demonstrated that any wave form, regardless of shape, can be considered to be made up of pure sine waves of various frequencies. If the proper amounts of each sine wave are added simultaneously, the original wave form is reconstituted. A wave analysis spectrum, therefore, is a graph showing the relative amounts of electrical energy donated by each frequency to make up the original wave form. This method of analysis has proved to be a powerful tool in analyzing the function of various types of complex electronic equipment. As applied to electromyography: should two wave forms obtained under the same circumstances from the same site consistently demonstrate markedly different wave-analysis spectra then the electronic parameters of each wave form are also different and, more important, the mode of production of each wave form must be different, or different units must be utilized to produce the two different wave forms. In substance, even though two wave forms obtained on the electromyogram may look quite dissimilar they may still show the same wave-analysis spectrum and therefore be produced by similar units. On the other hand, if the spectra are dissimilar, then the two wave forms cannot be produced by similar units (unless one postulates that the functional parameters of the units have* changed). Two points must be emphasized. First, even though the analysis breaks down a wave form into sine waves, this does not necessarily imply that the natural method of production of the wave was to combine these various sine waves. Second, the frequency spectrum applies to a single wave form; the frequency at which the wave appears (rate of action potential discharge) has no effect on the analysis and the analysis does not indicate the rate of discharge.

Wave analysis in the studies reported here was done from the magnetic tape recordings by isolating a 4.6-second section of the tape containing only the activity under investigation. This was set up as a playback loop running at the same speed as that used for recording. The output was bridged between a wave analyzer and one beam of the oscilloscope. The wave analyzer was of the continuously tunable filter type (Muirhead-Pamatrada) used in the maximum selectivity position (three decibels down at 0.6 per cent off tune). The graph points at intervals of twenty cycles per second were obtained by multiple recordings of the analyzer meter at each point throughout the range listed. In all instances, to obviate any effect of sixty-cycle interference, the position of sixty cycles per second was not recorded on the graph. Since the analyzer is used in the narrow-band position this in no way invalidates tiny other portion of the curve. The analyzer output was fed to the other beam of the oscilloscope, permitting a visual and photographic display of the amount of energy at any frequency range, compared with the wave forms presented on the other beam. The wave analysis setup is illustrated schematically in Figure 2.

The subjects were supine on a sponge-rubber mat, and sponge-rubber blocks one-inch thick were placed below the knees to effect complete relaxation. To obviate pain impulses from the skin about 0.1 cubic centimeter of 2 per cent procaine was injected intradermally at each insertion site. Multiple sites were evaluated within each muscle. Each site was subjected to the same sequence of events: rest, voluntary contraction, a series of ten passive stretches, and then terminal voluntary activity. Responses to needle insertion and movement were also evaluated. The passive stretch was effected by manually moving the appropriate joint through an arc of approximately 50 per cent of the normal range of motion. Each stretch cycle lasted about five seconds and there were no pauses between the stretches. Muscles routinely evaluated were: the gastrocnemius, the soleus, the anterior tibial, and the long and lateral heads of the triceps humeri

Subjects were chosen from the patient population of the orthopaedic and neurological wards of this general hospital. Normal volunteers were patients recovering from a variety of minor orthopaedic procedures done more than one month before. They were all completely ambulatory and exhibited no signs or symptoms of neuromuscular disease. In no case was an extremity evaluated on which an operation had been performed. Patients with neurological diseases included those with herniated disc, polymyositis, and what was considered to be benign epidemic myalgic encephalomyelopathy. The criteria used for the selection of cases and the characteristics of the cases will be discussed in corresponding portions of the following section. (A total of thirty persons was evaluated by the methods described.)

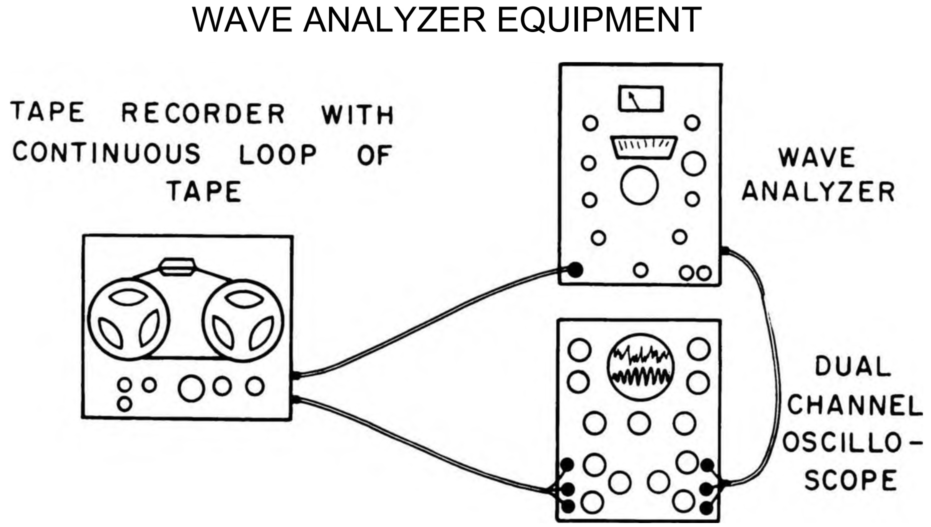
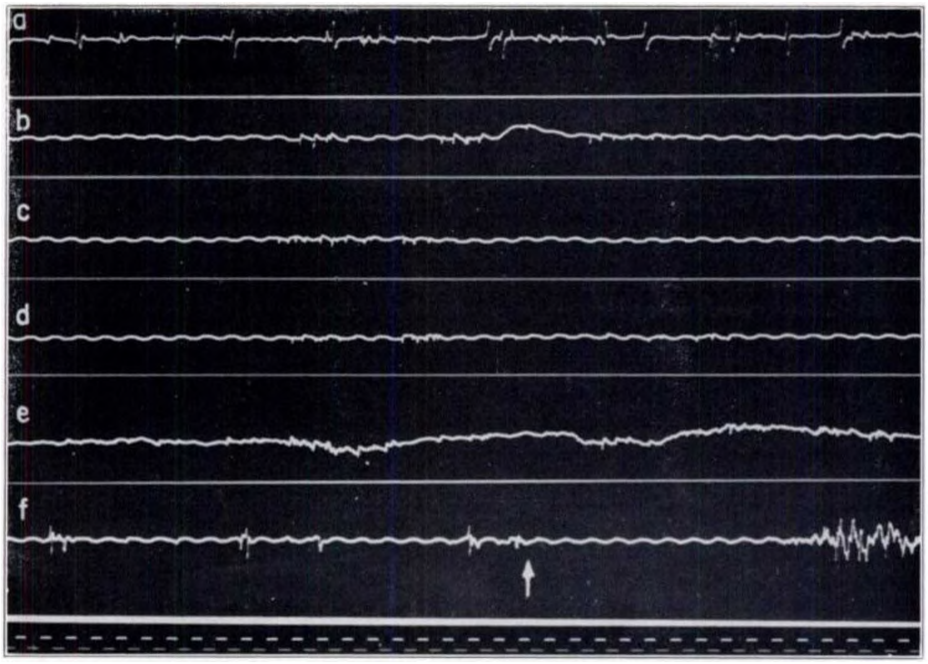


FIG. 2

Diagram of the experimental setup used for the wave-analysis procedure. The tape containing only the group of wave forms to be analyzed is made into a loop of specific length and played back repeatedly by the tape recorder. The output of the tape recorder is bridged between the wave analyzer and one beam of the oscilloscope. The individual sine wave sequences isolated by the wave analyzer pass to the output meter and to the other beam of the oscilloscope. The amplitude of each sine wave indicates the relative proportion of that specific frequency which goes to make up the original wave form.

RESULTS

In all eight normal volunteers electrical responses to passive stretching were noted in the long head of the triceps and in the soleus muscles. The anterior tibial muscles also showed similar activity, but it was of lower magnitude and not consistent. The gastrocnemius and the lateral head of the triceps were uniformly silent to stretch. In the soleus and long head of the triceps the activity appeared as a high-frequency discharge, predominantly positive and occurring as a burst generally 0.01 to 0.02 second in duration, just before maximum stretch was reached or just after the relaxation phase began. This relationship to the phase of the stretch cycle was constant in all cases. The amplitude of the activity was uniformly low during the first stretch (under 50 microvolts) and decreased in magnitude with each succeeding stretch until it was no longer visible after the third or fourth stretch. The low level of activity in these normal muscles necessitilted running; the amplifiers at twice the usual gain. This produced a readable wave form without distortion but did increase the level of sixty cycles per second interference (Fig. 3, *b,* c, and *(I).* The most common wave form encountered was an initial sharp positive deflection, followed by a slower return to the base line. This w:is most easily visualized on the first stretch where the magnitude enabled easy visualization (Fig. 3, /»). As t he magnit tide diminished or the repet it ion rate increased or as both of these* phenomena look place, the discharges appeared more random in nat lire although they usually retained their predominantly positive sign. ()ne is led to believe, when watching these events, that the discharges are from the same source in all cases, and that the basic wave form is the one appearing on the first stretch. Visually, this activity is quite easy to distinguish from the activity associated with voluntary contraction and recorded from the same site (Fig. 3. «). It was noted that approximately one site in five sampled would show thi* stretch response in either muscle, the other sites being silent to stretch. However, a silent area was always silent to stretch regardless of the number of stretch cycles used, and an area demonstfitting the stretch response continued to do so provided a few minutes rest was permitted between each of the stretch series. When the electrode was retracted approximately five millimeters from an area showing the stretch response, no activity was noted on passive stretch. If the probe was then replaced as accurately as possible in its previous position,



FKS. 3

Electromyograms from stretch-sensitive area of the soleus muscle of a normal subject. <*i* indicates voluntary activity: />. response to first stretch: r, response to second stretch: </. response to third stretch: r, maximum response obtained from same area, first stretch of second-stretch cycle: and /, terminal voluntary activity. The arrow indicates cessation of the voluntary activity: the wave forms following the arrow are a spontaneous burst of high-frequency activity.

The voluntary activity is normal in pattern and amplitude. The stretch responses (6. c. and d) are typical positive waves of high-component frequencies, diminishing from the first stretch to the third. The stretch response in c is a more marked response and. although still mostly positive in sign, shows the result of interference between wave forms. In all eases the difference between the voluntary activity action potentials and the stretch response is apparent. (Calibration signal sixty cycles per second and fifty microvolts amplitude.)

the same stretch responses were obtained. It therefore appeared that small discrete areas were responsible for the activity. In two of the normal subjects evaluated, areas within the soleus that produced the stretch response also showed bursts of similar high-frequency activity either during the initial portion of or following the cessation of, the terminal voluntary contraction (Fig. 3. /'). These patients volunteered the information that they felt a simultaneous, involuntary shift within the muscle. Occasionally, short bursts of high-frequency units could be produced by needle insertion or movement in the soleus muscle These were inconsistent and lower in amplitude than those obtained in response to passive stretch and did not show potentiation with repeated needle movement

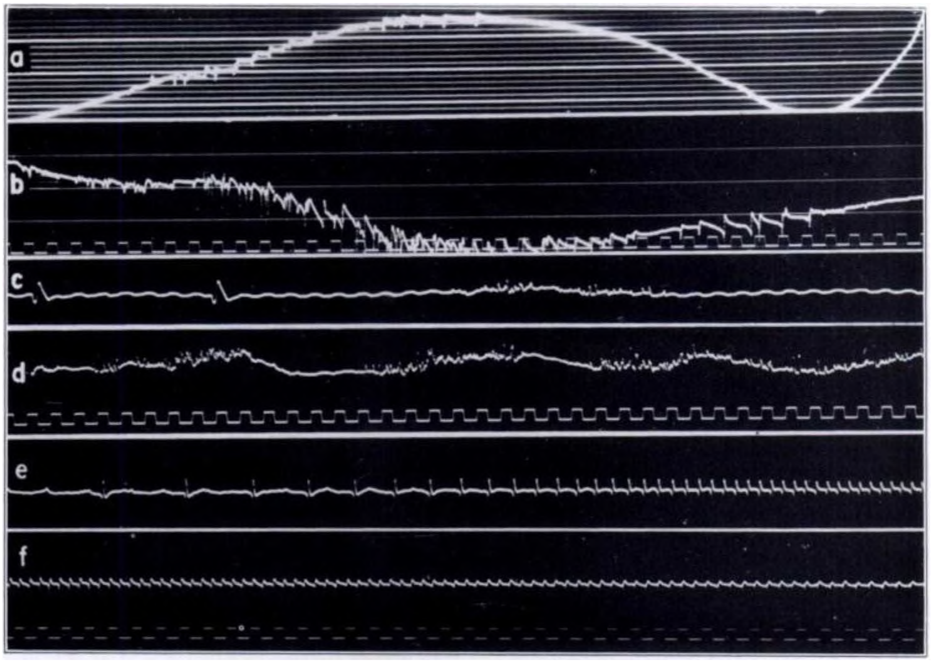


FIG. 4

Stretch responses of muscles in patients with herniation of an intervertebral disc and patients with polymyositis. *a* indicates response to first stretch (soleus) in a herniated-disc lesion (fifth lumbar-first sacral); *b.* response to third stretch, same patient and same site as <*i; r.* response to first stretch (soleus) in polymyositis; *il.* response to tenth stretch, same patient and same site as *c;* and c and *f* indicate continuous record of response to first stretch of long head of triceps- polymyositis with atrophy of the triceps. The initial positive deflections in *f* do not register on the print. (Calibration signal sixty cycles per second and 100 microvolts amplitude.)

The wave forms in Fig. 4 should be compared with those in Fig. 3. Their similarity to the stretch responses in normal muscle is evident, a sharp initial positive phase followed by a slower negative phase. The initial amplitude is much greater than in the normal subject and the amplitude increases with repeated stretching (« and />). All of these wave forms are clearly different from those seen during voluntary activity.

Eleven patients with herniated discs in the lumbar region between the fourth lumbar and first sacral vertebrae' were evaluated; the condition was proved at operation in eight patients and myelograms were positive in three. Patients with minimum clinical signs were deliberately chosen: none showed fibrillation or fasciculation potentials. (In my experience these signs tire usually associated with severe nerve-root compression, in which case the clinical diagnosis is evident.) Electrical responses to stretch identical with those described in the normal subjects were noted in the soleus muscles. These bursts of electrical activity retained the same consistent relationship to the phase of the stretch cycle as was previously noted in the normal subjects. The amplitude, however, was much greater (over

100 microvolts) and the discharge increased with succeeding stretches sometimes associated with shifts of the base line (Fig. -I, <7 and 6). The increase in the discharge consisted in increases in the amplitude of the discharges and in the frequency of individual pulses, as well as an increase in the duration of the total discharge. (In a tew cases the terminal contraction was followed by a burst of similar high-frequency units.) This increased activity was uniformly present on the same side as the herniated disc, the contralateral extremity showing a normal reaction, that is, a decrease with each succeeding stretch. In those subjects in whom a herniated disc was present between the fourth and fifth lumbar vertebrae, the anterior tibial muscle on the affected side was usually slightly weaker to clinical testing than that on the contralateral side. Nevertheless, the stretch responses of these two muscle groups were equal. of very low amplitude, and sparsely scattered throughout the muscle bulk. The gastrocnemii on both sides were silent to stretch procedures.

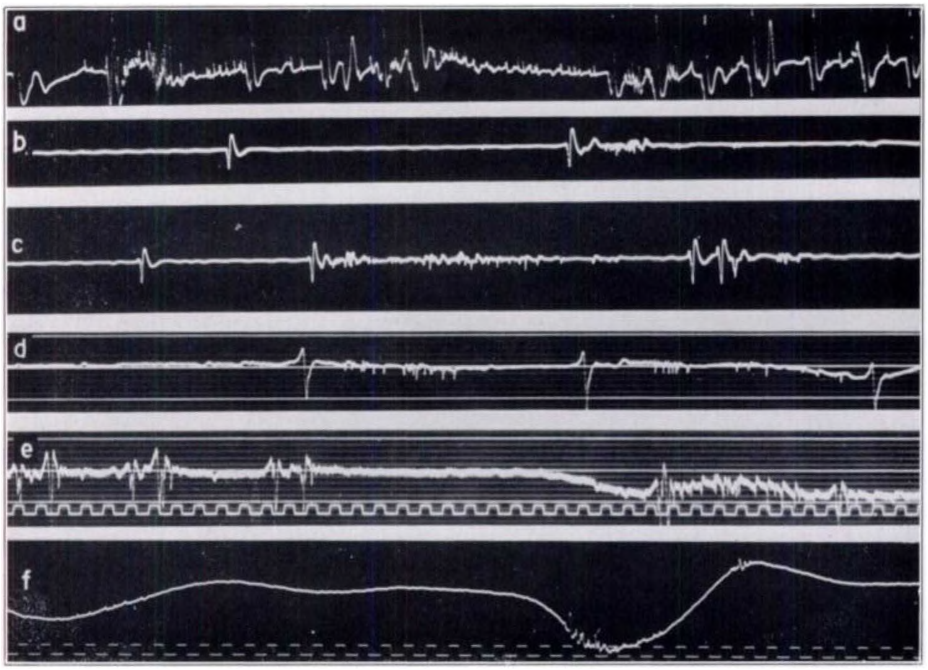


FIG. 5

Fleetroniyograms in polymyositis, *a* indicates the high-frequency activity occurring initially during voluntary activity of the soleus: />, c. and d indicate the high-frequency activity following fasciculation impulses of the soleus: c indicates the burst of high-frequency activity following voluntary activity oft he triceps (note also t he poly phasic action potentials): and/, I he high-frequency activity occurring during needle movement, (Calibration signal sixty cycles per second and 100 microvolts amplitude.)

All of these electromyograms show spontaneous activity similar to that found on stretching. In each case, however, there was a change in the tension-length relationship of the muscle such as t he beginning or ending of a coni faction that brought about t he burst of high-frequency units.

Fight cast's considered to be polymyositis were evaluated. Clinically, these patients showed muscle weakness and atrophy about the shoulders and hips, as well as severe cramps in all ext remit it's. 1'hey were evaluated joint ly by t he medical, neurological, ami ort hopaedic staffs ami concurrence in I he diagnosis was reached, using the criteria of Eaton. In seven of the cast's biopsies of the involved muscles were compatible with the diagnosis. In all of the cases, diagnoses of anterior horn-cell disease or muscular dyst rophy were considered less tenable than polymyosit is. All patients in this group displayed high amplitude potentiating stretch responses identical to those previously described in the subjects with herniated discs (Fig. 1. *c. <1. c,* and /). These responses were particularly easy to produce, requiring only a minor amount of stretch, and they appeared much more uniformly distributed throughout the bulk of the muscle than in either the normal subjects or those* with herniated discs. In the triceps muscle, atrophy was commonly encountered and decrease in the muscle bulk may be the explanation for the ease with which the stretch response was elicited in this muscle. The soleus muscle, however, was usually not involved in the atrophic process although it was also subject to severe cramps. Other observalions included: the occurrence of after-discharges consisting in bursts of the same high-frequency units which followed fasciculation impulses (Fig. 5. 6, *c.* and </). needle movement (Fig. 5./). and voluntary contractions (Fig. 5, (). Responses to needle movement were frequent, but they did not show potentiation to repeated stimuli (movement). Occasionally, the terminal voluntary activity showed high-frequency units in its initial portions (Fig. 5. *a).*

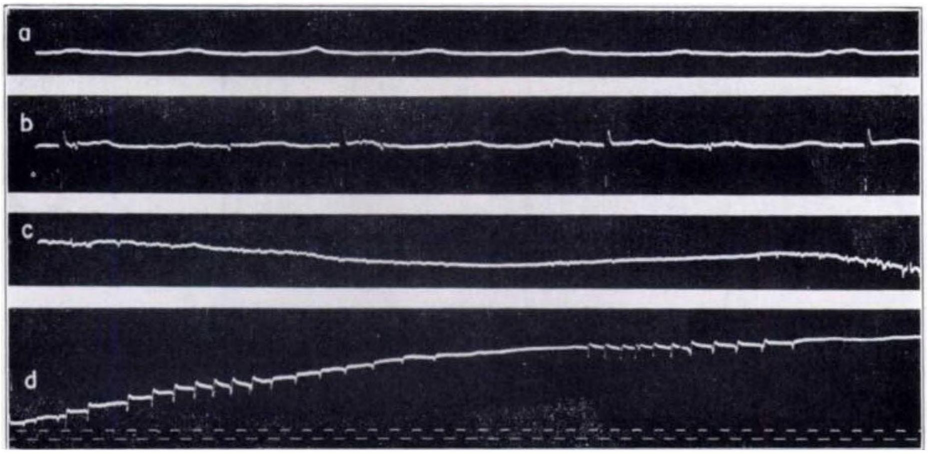


FIG. 6

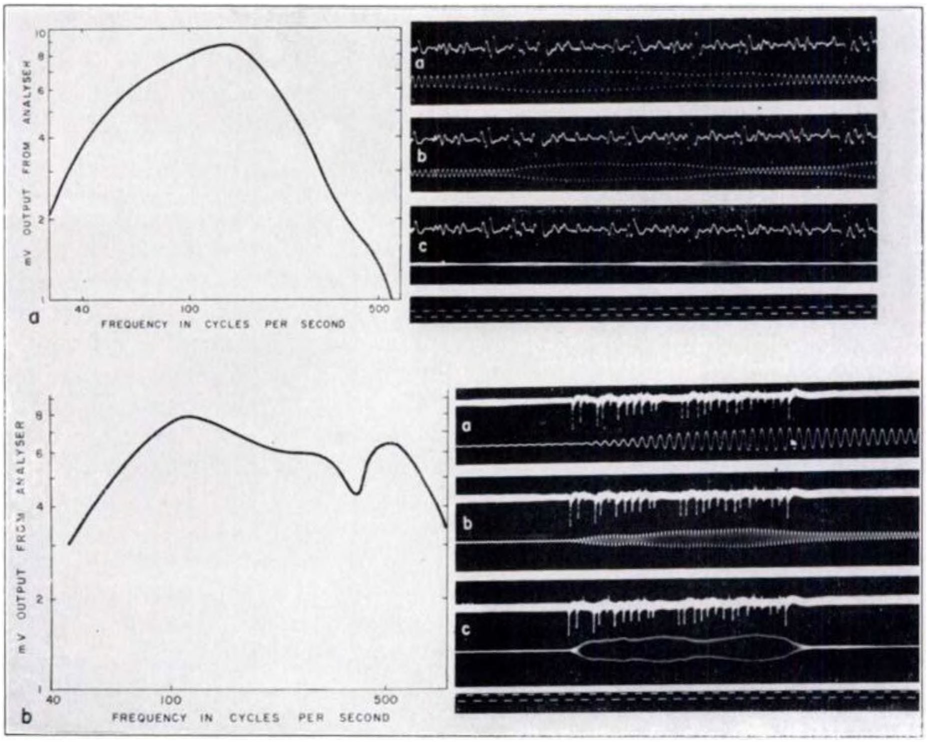
Elect romyogranis from the soleus of a patient with benign epidemic encephalomyelopathy. *a* indicates resting, showing spontaneous slow wave potential: b, voluntary activity, showing scarcity of motor unit potentials, as well as the large amplitudes of these potentials and their clear wave forms: r. response to first stretch, showing small wave potentials: and </. response to third stretch, showing potentiation. (Calibration sixty cycles per second and 10(1 microvolts amplitude.)

The stretch responses arc again of the same type as in the other illustrations. There is again an increase in the amplitude of each wave and in the total number of waves with repeated stretching.

In polymyositis, the biceps muscle usually was severely involved in the process and although electromyographic determinations were made on it in the same manner, stretch could not be readily accomplished by elbow motion. However, by manually grasping the biceps tendon and deflecting it sideways the muscle could be put under some stretch tension, Under these circumstances no electrical responses were noted to the cyclic st retching procedure. After-discharges were noted following voluntary contractions, but these were not high-frequency bursts.

Three cases studied were considered to be benign epidemic myalgic encephalomyelopathy on the basis of the clinical findings. The clinical characteristics of this condition are much less clearly defined than polymyosit is and therefore the diagnosis is somewhat in doubt [,2 ;:4]. These patients gave a history of sudden onset of the disease. Headache, nausea, vomiting, and pyrexia were followed by muscular weakness accompanied by severe peripheral muscular cramps. As the acute symptoms subsided, weakness and cramps remained in scattered muscle groups—generally in the muscles of the pelvic and pectoral girdles and demonstrable atrophy appeared. It was during this phase of atrophy that these patients were evaluated. Xo special treatment was subsequently rendered and all three patients made gradual but complete recoveries. In two, the triceps muscle was involved; it demonstrated high amplitude' ami potentiating stretch responses. In the third patient the* e-alf muscles were[1] involved and the soleus showt'd the' same* reaction (Fig. 6). In each patient the* other muscle's we're[1] evaluated: the[1] results were[1] identical to those recorded in the[1] normal series.

Wave[1] analysis was performed on recordings from selected subjects in each group. In each case[1] voluntary activity ami stretch responses taken from the[1] same[1] site[1] within the muscle[1] were evaluated. The voluntary activity spectrum was identical to that reported by either workers " -[1] (Fig. 7. a). The[1] spectrum of the



!Tc. 7

a: A wave analysis of voluntary activity. At t he left is t he graph obtained from the output nt.-ter of the wave analyzer. The horizontal scale[1] represents the frequency of the sine[1] waves; the vertical, the amplitude at each frequency. The major contribution to the voluntary wave form is in the section labeled 1(H) to 200 cycles per second. At the right are three representative oscilloscope tracings for three[1] different frc<|Uencics. In each case the upper line is the electromyographic waveform group being analyzed and the lower tracing is the sine wave content at the single frequency listed: *a* = 150 cycles per second, *h* = 200 cycles per second, and c = 500 cycles per second. The verv small contribution from the freeiuemcies of 500 cy< les per second is evident.

b: A wave analysis of a typical stretch response. The graph at the left demonstrates a rather marked peak in the section labeled 500 cycles per second with amplitudes here equaling those at 150 cycles per second. The oscilloscope presentations at the right are for the same frequencies as in Fig. 7. «. and the large amount of energy at 500 cycles per second in the wave form is clearlv evident.

stretch response wtts in till cases markedly different from that of the voluntary contraction, showing a displacement toward the higher frequencies with a consttint peak in the region of 500 to 600 cycles per second (Fig. 7, b). The same spectrum was obtained from all the stretch rm-ords analyzed regardless of differences in wave form. Even when the sharp positive wave forms were particularly prominent (see results with normal muscles) the spectrum of the stretch response was not altered.

DISCUSSION

Electrical activity associated with passive stretch has been found in certain muscles of thirty subjects. This activity always maintained a definite relationship with the phase of the stretch cycle and was uniformly of a wave form visually and electronically distinguishable from the activity associated with voluntary contraction. In the normal subjects the activity decreased with succeeding stretch cycles, whereas in patients with disease characterized by hyperirritability of the skeletal muscles the activity increased with succeeding stretches. The soleus and long head of the triceps consistently demonstrated the activity, whereas the gastrocnemius was uniformly silent. The anterior tibial and lateral head of the triceps showed very sparse activity.

Similar wave forms have been encountered in denervated muscle or muscle rendered hyperirritable by peripheral nerve lesions [16] or polymyositis [19] and in so-called normal muscles of the anesthetized rabbit [20] and the muscles of rabbits on diets deficient in alpha-tocopherol ’. In all reports the wave forms were noted spontaneously or on needle movement ; passive stretch was not carried out.

It is felt that the activity reported herein is genuine and does not represent interference or artifacts arising within the apparatus. In the normal volunteers the increase in the gain produced an increased sixty-cycle artifact, but the stretch response wave forms were clearly evident on inspection of the records. In these cases the frequency band of sixty cycles per second was also excluded from the wave-analysis graph and therefore did not influence the results of this procedure. In all patients, both normal and diseased, the voluntary-activity wave analysis agreed closely with that obtained by other workers. It is therefore concluded that this method of dealing with interference of sixty cycles per second is well within the limits of standard accuracy. It is further concluded that pain stimuli were not connected with the phenomenon since the same technique was uniformly employed throughout the study; however, in all the subjects evaluated, the soleus muscle reacted to stretch with electrical activity, whereas the gastrocnemius—its immediate anatomical neighbor—was uniformly silent. The degree of discomfort would seem to have been nearly identical in both instances. However, the correlation between the presence of the activity and the acknowledged postural function of the soleus is evident [5]. The bursts of activity occurring in response to needle insertion and movement appear to be the same as those occurring during passive stretch. Potentiation was never noted in the needle movement series; however, it was definitely present in the stretch series. It is therefore concluded that the responses obtained during stretch are the results of the stretch stimuli and not the result of needle movement accompanying stretch. However, it cannot be said that the activities produced by stretch and needle movements are not produced by the same anatomical units. The same motor units may be stimulated by both needle insertion and stretch. If these fibers are analogous to the slow fibers of invertebrate muscles then they should be capable of local, non-propagating responses, and needle insertion or movement could produce this type of reaction. The important point, however, is that the stretch responses differ quantitatively from the responses to needle insertion. One explanation for this difference would be that stretch obviously involves the entire muscle as a functional unit and that the potentiation produced is the result of the activity of all portions of the tonic neuromuscular system, not just the local fibers.

The occurrence of the stretch response from restricted sites within the muscle bulk and the reproducibility of results (see section on normal muscles) indicate that under the experimental conditions the tip of the probe remained relatively fixed within the same area for the entire test event sequence. This fact, in addition to the small area of signal pickup of the probe used, mediates against the activity recorded being distant units with wave-form distortion produced by travel through the muscle bulk. Under these circumstances the application of wave analysis to the two types of activity would seem to be valid.

The possibility that these responses result from activity of the intrafusal fibers within the muscle spindles cannot be ruled out. Boyd is of the opinion, based on histological evidence, that the small intrafusal fibers may be analogous to the slow tonic fibers of invertebrates. At present, however, definite evidence as to the abundance of the spindles within human postural muscles is lacking. They are known to be plentiful in the extra-ocular muscles and the intrinsic muscles of the hand, but can only be presumed to be more abundant in the postural muscles of the limbs than in the non-postural muscles in the same areas[2]. The results described in the present paper would indicate that if the responses were arising in the intrafusal fibers, then the spindles are much more numerous in the large postural muscles than they are thought to be. They would also be of greater importance than is generally thought. Although at this time the question must remain open until more definite histological evidence is forthcoming, it appears unlikely that the spindle fibers are the source of the activity recorded.

The constancy of the character of the discharge, the visual and electronic differences between it and the discharge accompanying voluntary contraction, the difference in potentiation between the normal and disease states, and the occurrence of the discharge primarily in postural muscles, all indicate that the activity recorded is genuine and that it represents a specific reaction of certain areas of the skeletal muscle to passive stretch. Whether these areas are composed of a different type of muscle fiber has not been determined. The electrical parameters of the discharge in the stretch response are sufficiently different from those of voluntary contraction to indicate, at the very least, a difference in the method of production.

It is not within the scope of this paper to attempt a complete review of the various aspects of the dual neuromuscular system. The interested reader is referred to the excellent monographs of Hoyle and, particularly, of Kruger. For clinical understanding, however, it may be said that this system provides for two separate complete neuromuscular systems. One system, functioning automatically through specialized neural connections, acts upon specific muscle fibers by means of multiple end plates. These specific muscle fibers are capable' of slow, sustained contractions of low magnitude with great resistance to fatigue; these fibers generate only local, non-propagating, electrical impulses. The other system, operating through neural connections of a voluntary or semi-automatic nature, acts upon muscle fibers by means of single end plates. These muscle fibers tire easily but generate propagated impulses throughout their length and contract very quickly and with great force. The entire system has been fully investigated and all components found and studied in the invertebrates. In the frog the slow muscle fibers have been located, whereas in the cat only the specialized anterior horn cells have been thus far described. In the peripheral musculature, however, fibers with multiple end plates have been described histologically in the monkey by Feindel and associates and electrically in the cat by Hunt and Kuffler. Previous attempts to obtain electromyographic evidence in the human being of specialized postural fibers have been unsuccessful [13,22]. The present paper is the first attempt to obtain such information based on the known parameters of the specialized anterior horn cells, as described by Granit and associates and Eccles and associates, and the known parameters of the tonic muscle libers, as described by Hoyle. The criteria utilized were:

1. The electrical activity of the tonic fibers should be distinguishable from that obtained during voluntary activity, both visually and electronically;
2. The electrical activity should be related consistently to the phases of the stretch of a muscle containing such fibers;
3. Potentiation of the activity should occur with repeated stretching;
4. Such activity should be present in greater abundance in muscles with a postural function (although this does not obviate the possibility of such fibers being present in other muscles, for example, in those requiring very fine, controlled motions).

Each of these criteria appear to have been fulfilled in the present study. The clinical importance of the exaggerated tonic fiber activity (on electromyography) in certain diseases is obviously an immediate diagnostic aid but may also become ef even greater importance therapeutically as more information is obtained relative to the entire human neuromuscular system.

SUMMARY

A refined technique of electromyography and electronic analysis was utilized to determine the responses of several muscle groups to passive stretch. Distinctive responses were obtained in the soleus and long head of the triceps humeri. In the normal person these had a definite relationship with the phase of the stretch cycle, were about fifty microvolts in amplitude initially, and diminished on repeated stretching. In patients with disease characterized by hyperirritability of the skeletal musculature, the same responses were obtained in the same muscles. However, in these subjects the initial amplitude averaged 100 microvolts and repeated stretching produced a marked increase in amplitude and duration of the discharge. In all subjects the responses were confined to multiple discrete areas within the muscle bulk. The gastrocnemius and the lateral head of the triceps were silent to repeated stretching. A few scattered non-potentiating discharges were found in the anterior tibial muscle of some of the diseased patients.

The possible sources of error in the investigation are considered and discussed in relation to the findings. These results correlated well with tentative criteria for the presence of tonic muscle fibers, based on recent indentification of tonic anterior horn cells in the cat. Further investigation in clinical syndromes seems warranted. The activity in the patients with neuromuscular disorders appeared to be analogous to the activity of the tonic motoneurons in decerebrate preparations. The experimental results indicate some duality of function in the skeletal musculature of the human being.

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