Section of Physical Medicine

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Some Studies on Muscle Tone

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The object of this lecture is to consider the modern physiological conception of muscle structure, muscle contraction and muscle tone, and the relationship these should bear to our conception and practice of Physical Medicine as it is to-day.

The *concept* of muscle tone seems to be of importance and has often been discussed in relation to physical education, remedial exercises, posture correction, economy of work, and the mechanics of locomotion. In rheumatology it influences our conceptions of contractures, reflex contractions of the muscles, muscle spasms, and the tender, palpable nodules of the muscles, the so-called myalgic spots. The different modern procedures called relaxation have to be evaluated in relation to our knowledge of physiology.

We must be able to analyse this concept before we can select suitable physiotherapy for an individual case.

On this occasion we will consider only the influence of electromyography.

It would seem to me that the following definition includes the primary concept of muscle tone in the light of modern knowledge and contains the fundamental idea of muscle tone as being essentially a "passive elastic tension". We may say, therefore, in relation to muscle tone that all the striated muscles in the normal body are in a condition of slight tension independent of voluntary or reflex stimulation through the motor nerves. The muscles are always in situ stretched a little beyond the length of equilibrium and thus possess a certain passive elastic tension. (Some two-joint muscles may be relaxed almost to equilibrium, if the joints are moved into artificial extreme positions, but this is of less importance in this connexion.)

Hitherto many physiologists have *wrongly* thought this slight tension was due to a reflex activity through the motor nerves. This idea has developed through the years because of the analogy drawn from the experiments on decerebrate animals, and we have been led to presume the existence of a slight sustained contraction, a few motor units working at a time, in relays. This supposed automatic reflex activity and constant reflex contraction have been defined as muscle tone and it has been thought to persist and to determine the resting positions. In most modern textbooks it has been described as a sort of "stretch reflex" similar to decerebrate rigidity. Many of us had considered this presumed reflex tone an active reflex stimulation always present in all striated muscles. We had not sufficiently appreciated the difference between the condition in the decerebrate preparation and the condition in normal individuals in whom the inhibition from the brain of motor reflexes is preserved.

Some authors, however, follow Sherrington, who said in 1915: "Reflex tonus obtains in, and is confined to, those muscles which maintain the animal in an erect attitude", and also "Reflex tonus is postural contraction". Consequently, they left muscle tone out of consideration in the muscles which do not counteract gravity. They discarded the concept of a general tone and spoke only of a postural reflex tone confined to the extensors and the standing position. They ignored the concept of a universal muscle tone.

In 1924 Lidell and Sherrington described the "myotatic" or what we now consider as the true stretch reflex proper. In more detail this explains that if a passive stretch of an antigravity muscle is imposed, a number of its proprioceptors are stimulated and their respective motor neurones excited. Increase of the stretch is accompanied by increase in the number of its proprioceptors stimulated, and of the motor neurones excited which supply it. If the stretch ceases, the activity immediately subsides.

Postural reflex tone of the antigravity muscles is now known to be due to this stretch reflex, whereas stretch reflexes of the flexors are of less significance, if of any at all.

In the horizontal position, the postural reflex tone also subsides, but still a certain passive tension persists—as the muscles are stretched a little beyond the length of equilibrium.

In 1929, it was made possible to solve the problem of active or passive tension and to distinguish between passive tensions and active contractions when Adrian and Bronk devised their needle electrodes, which could be inserted into the muscles of human beings, and there pick up the electrical potential variations accompanying the stimulation and activity of a single or of some few fibres. Since then it has been made possible to distinguish between *passive tensions* and *active contractions*. The normal resting muscle presents no potentials whatever, and no evidence at all of any slight sustained stimulation.

"Motor tone" at rest does not exist, passive elastic forces only are the causes of the tensions of the resting muscle.

In Physical Medicine we must not use such terms as "spasms", "reflex contractions", "contractures", "relaxation", or "variations of muscle tone" without taking the results of the electromyographic studies into consideration (Harrel, Mead, and Mueller, 1950).

We must distinguish between "*active*" (voluntary or reflex) stimulation through the motor nerves, and in respect of what we previously considered as muscle tone, the "*passive*" elastic tension and forces.

Firstly, there are two possibilities of which we should be aware. It may be that a certain tonic stimulation exists through the autonomic nervous system. The striated muscles have their direct sympathetic system, and it may have some direct influence on the consistency and elastic properties of the muscle fibres, besides having an influence on the circulation of blood in the muscles, but this activity does *not* give rise to action potentials which can be registered by electromyography.

Again we must not come to any definite conclusions until more knowledge is available of a certain motor system of thin nerve fibres described by Häggqvist (1940), though this again is not known to have any observed effect recorded by clinical electromyography.

Bearing these reservations in mind, we may pass to the more general and important consideration of "passive elastic tension". Every motor stimulus passing the end-plates is accompanied by action potentials, whether the stimulation is voluntary or reflex. Muscle fibres at rest do not show any potential variations. Therefore, electromyography makes it possible to distinguish between the active and the passive forces and tensions.

Let us now try to analyse our daily clinical problems concerning muscle function from this viewpoint.

The passive tensions must be due to the muscle structures as a whole, the active tensions to the contractions of certain muscle structures.

In spite of voluminous literature in recent years concerning the ultrastructure of the muscle fibrils, much remains to be explained.

The studies of Meyer (1924) and Astbury (1939) indicate that the long molecular chains are the ultimate machinery of contraction.

Undoubtedly, the folding and unfolding of protein chains play a role in the *active* mechanical behaviour of the myosin chains during muscle contraction, but even then a *passive* elastic function as well as a plastic deformation must be assumed to result from the effect of stress and strain. The passive elastic processes are also considered to be due to the uncoiling of chains and stretching of "bonds". The plastic processes are regarded as the flow (or slippage) of chains past one another, the so-called shearing.

Both the active and the passive process are influenced by (1) temperature, (2) mechanical deforming forces, (3) osmotic forces, (4) hydrostatic pressure, (5) chemicals, (6) blood circulation, (7) dehydration, and (8) pH. This is known from experiments with artificial myosin threads, and from experiments with isolated muscle fibres.

The degree of *passive* extension and consequent uncoiling of the molecular chains must be influencing the possibility of *active* coiling and contraction. This point reveals the weakness of the apparently clear and simple electromyographic distinction between "active" and "passive" forces.

However, we may be allowed to consider that we have built up from the elements of this background the synthesis of the conception of the passive elastic properties of the muscles, well knowing that these so-called passive elastic forces are variable and may be influenced by the factors mentioned. It is obvious that these passive elastic forces in the fibre must be added to the elastic tension due to sarcolemma and other structures. It is therefore an over-simplification to speak of the "viscosity" and "molecular chains" of the muscle fibre.

We will now discuss what happens to the passive elastic forces, when a muscle is stimulated and contracts.

The tracings of Adrian and Bronk (1929) showed how the contraction of a muscle starts through the arrival of stimuli at one or a few motor units in a rhythm of about 5–6 per second. Then, as the magnitude of stimulation and contraction becomes greater, more units come into function, and the rates of stimuli reach 30–40 per second, rarely as high as 50. Clinical electromyography with a good apparatus (Fig. 1) reveals the fact that, when it is possible adequately to isolate the action of a single motor unit, the individual motor unit discharges normally at a relatively low rate. This refers to and is the same during ordinary movements as well as in ordinary reflexes. Such rate of stimulation is not sufficiently high to cause a tetanus of the single fibre, as seen in artificial stimulation.

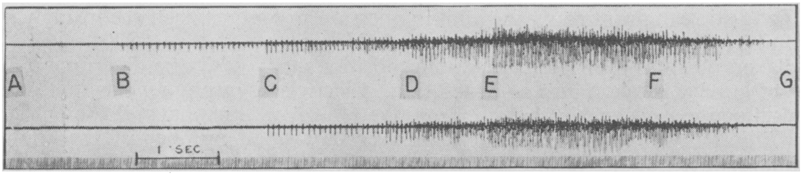

FIG. 1.—Electromyogram from a normal muscle. 2 leads. 2 double channel needle-electrodes. The distance between the two electrode-points is 0·2 mm. In all figures the horizontal line in the time marks one second.

In most of our daily volitional muscle contractions and in almost all our reflex movements, the muscle contractions are not tetanic contractions of the units. Even the long-sustained contractions are due solely to a quantitative summation of a number of asynchronously working motor units. Each motor unit contracts at its own rhythm, which is varied with the rate of stimulation. The train of successive impulses and twitches is graded as to frequency and adjusted to the demand of tension. When the contraction is more powerful, fresh motor units are brought into play, and new and higher rhythms are observed.

In most of the muscles the single fibre does not extend the whole distance throughout the muscle from one tendon to the other. At the same time, it is a fact that only as an exception and only in powerful contraction may the fibres be in tetanus, and even then hardly all of them. Consequently, isometric and isotonic contractions are distinct phenomena in isolated fibres. (Moreover, it is evident that the degree of passive extension and consequent uncoiling of the molecular chains must be influencing the active coiling and contraction obtained through stimulation. This fact is, furthermore, the explanation of the different powers and tensions developed in the muscles when they are working respectively concentrically or excentrically and during lengthening or shortening movements. If the molecular chains are thought to be coiled up until maximum before stimulation, further contraction should not be possible. From this, it must be evident that we should not extend direct analogies from experiments on isolated muscle fibres to whole muscles.)

The smoothness of the contraction of the whole muscle, and the delicate gradation shown, are due to the interaction of the active units with the momentarily passive ones, and the resulting force reacting in association with the other passive elastic structures and forces of the muscle and of the passive elastic forces of the natural antagonist.

A fusion of the forces from the successive individual twitch contractions of the different units takes place, and a graded tension is transmitted to the tendons of the muscle.

The elastic properties of muscle conceal and compensate for the rhythmic stimulation found in postencephalitis without tremor (Buchthal and Clemmesen, 1946) and likewise conceal the synchronous stimulation and activity so often found in poliomyelitis and other anterior horn lesions (Buchthal and Clemmesen, 1943). In spite of the rhythmic successive action of the motor units, the contraction of the whole muscle is usually smooth, even if, in some few cases, a regular, fine vibration may be felt by palpation, or heard in the stethoscope.

It is evident, therefore, that we must reckon with the passive elastic tensions and forces in the muscles, and that this concept is much more correct than the now discarded concept of muscle tone.

Our movements take place on a background of passive elastic tensions. These may, depending on the circumstances, assist or resist the movements, and they may be in play as synergists as well as antagonists. They may be and are exploited in economy of work, counteracting inertia and external forces.

Electromyography also demonstrates that quite considerable passive movements may be performed without releasing reflex activity in the muscle itself or in the antagonist, until a certain limit of extension has been reached. In active contraction, the yielding of the antagonist is often quite passive (that is: without stimulation, but not without tension).

In its application to Physical Medicine I shall now analyse the distribution between active and passive forces in the muscles in the horizontal position, in erect position relaxed, in erect position standing at attention, during walking, and during work.

In the supine position, *relaxed in a pool* with gravity eliminated, the joint positions are determined exclusively by the passive elastic tensions. The average intermediate positions of the joints may easily be determined, and are the same as the so-called resting positions. The average positions are determined through the equilibrium between the different muscle groups and their passive tensions. (If a group of flexor muscles is hypertrophic in comparison to its antagonistic extensor group, the joint in question will adjust itself accordingly in further flexion, and in a case of atrophy the contrary holds.)

In a relaxed position on a bed, the resting positions may easily be determined, when the influence of gravity is taken into consideration. Electromyography reveals that most of the talk of sustained muscle spasms has no meaning. However, Buchthal and Clemmesen (1940) and also Elliott (1944) have shown that in a certain small number of therapy-resistant, long-lasting, tender nodules of the muscles, a certain sustained activity, also at apparent rest, may be found most likely originating in the proprioceptors, and originally caused by continuous hyperfunction to protect a tender part of the body against strain and stress. After some time a sustained activity persists, also at rest, for some reason or other, possibly as a consequence of hyperfunction and fatigue.

Reflex spasms which are, during work or movements, defending a tender part of the body against stress and strain are often exhausting, because of the partially anaerobic conditions for the muscle. They may result in a sustained activity at rest, but usually they do not, and the reflex spasms will disappear, as soon as the patient is placed in a supine position comforted by pillows. This is also the case in acute lumbago and sciatica, in protruding disc, and in the adductor spasms found in hypertrophic osteoarthritis of the hip. Patients with acute muscular affections will, for the most part, avoid stress and strain of the tender parts, and reflex spasms occur in the synergists, in order to protect against movements of the sick muscles. Also these reflex spasms subside when the patient does not move or is placed on the bed.

In most diseases of the nervous system with increased tendon reflexes, and with *spasticity* and *rigidity*, no activity at rest will be found in the horizontal position. Exceptions are: myotonia, Werdnig-Hoffmann's disease, and the fibre activity after acute denervation. The movements which are found in chorea and myoclonia are, of course, accompanied by activity. In the tremor found in postencephalitis and in paralysis agitans, the activity subsides, when the patient is placed so that the end-points of the muscles are brought nearer to each other. On the other hand, the antagonists will often be brought into action through the extension.

The so-called reflex spasms of poliomyelitis are, for the most part, found to be contractures and not sustained reflex contractions (Buchthal and Høncke, 1944). The sensitive, hard muscles which do not yield to passive expanding have lost their elastic properties for some reason or other; we do not yet know how or why. As it may be understood from what has already been said about the elastic forces, there are several possibilities. Why Kenny packings, Priscol, and caffeine have some effect and undoubtedly improve the elasticity of the muscle in passive movements is not known, but may be understood when the different factors influencing the elastic properties are remembered.

When salicylates are so effective against muscle pains, it may be due to the combined effects on the peripheral circulation and on the sensorium. Novocain injections in tender muscles will often stop reflex spasms, which are otherwise found during movements. The novocain injections suppress the activity of the proprioceptors, and with stronger solutions the motor end-plates are also influenced. They stop the pains through their anæsthetic effect, and improve the peripheral circulation through their influences on the vasomotor system. The same result may be obtained by injections along the nerve roots. In this case the result is obtained through an anæsthetic effect upon the roots of the sensory nerves. Quinine lowers the activity of the motor end-plates, while nerve sedatives limit the uneconomic reflex spread of stimulation. This is true also of psychological treatment. Histamine and heat improve the peripheral circulation, and influence the elastic properties in the same way as the other drugs mentioned.

Just these few examples point out how it is necessary in each single case to evaluate and find out which treatment should be preferred, and how the electromyographic results should influence our whole philosophy as to the means of acquiring the correct treatment by Physical Medicine.

Some of the local myalgic spots and nodules of the muscles felt by physiotherapists during massage may be caused by local influence of the many variable factors which determine the elastic properties. (In non-articular rheumatism these possibilities must be reckoned with, just as is the case with panniculitis and with the nodules of the deep fat layers, as described by Copeman and Ackerman, 1944.)

Next we shall discuss the muscle function in standing position and during movements.

The "*relaxed*" *standing position.* The position here is determined and equilibrium obtained by postural reflex tone in association with the elastic forces and in opposition to gravity. If the individual is somewhat excited, the postural reflex tone is more predominant, by reason of a greater and more extensive reflex motor outburst than is usually necessary when he is at his ease. The same is the case, if he is under influence of strychnine or alcohol, or if some pain exists. With alcohol the central inhibition is partially abolished, with strychnine or pains the central irritability seems augmented.

It appears that we must not transfer deductions directly to ourselves from the results obtained by experiments with the bulbo-spinal preparations. In the decerebrate animal the reflexes occur very easily, and on slight afferent stimuli from the periphery or from the muscles, but *even here a certain amount of afferent stimuli must be present to initiate and sustain the reflex contractions, or else the muscles will relax.* We may presume that it is likely that we are, in daily life, able to exploit the instinctive and acquired reflex mechanisms with the control of our volition superimposed. We initiate and start complicated chains of reflexes (as while walking or driving a car) supervising and controlling the further play of reflexes, interfering only when something is wrong.

We are aware that most of our daily muscle work is done subconsciously (reflex). We are also aware that we are often unable to perform a discrete isolated contraction of our so-called voluntary muscles, a teasing fact during clinical electromyography. Many muscles are out of command, and it differs much from one individual to another, as to how skilled each of us is in this respect.

All our voluntary movements take place on a background of reflexes, but whether the reflexes are brought into action depends on the amount of afferent stimuli and their ability to overcome and break the central inhibition. In normal individuals the central inhibition seems to play an important role, and the postural and other reflexes are released only to the extent strictly necessary as an addition to the passive elastic forces, in order to obtain and maintain equilibrium with gravity, external forces, and inertia.

In the decerebrate animal a slight amount of afferent stimuli is sufficient to start and sustain the chains of reflexes, and every movement will, therefore, take place in a predetermined way, just as the whole posture is influenced. In normal human beings the chains of reflexes will not be released so easily, and they will not dominate the movements and the carriage to the same extent, a fact which has now been shown through electromyography.

In 1942 Seyffarth described how patients were able to *stand in the erect position* without any active stimulation of the calf. Using mostly skin electrodes, Åkerblom (1948) found this to be so, when the weight was over the heels. The quadriceps femoris too was not stimulated when in a comfortable standing position, that is with the knees locked and the line of gravity falling in front of the weightbearing line of the knee-joint. In the lumbar part of the erector spinæ he found only slight activity, if any, whilst during forward bending a strong activity occurred in the same muscle.

In the upright *sitting* position without support of the back, Åkerblom found a certain activity in the lumbar as well as in the thoracic part of the erector spinæ. The activity was considerably diminished and almost disappeared both in the *slack forward sunken* position with the spine in kyphosis and during *backward sloping with support* in the lumbar region or with support both in the lumbar and the thoracic region. (The action of the interarcuate ligaments was mentioned as the main elastic structure limiting the ventriflexion of the lumbar spine in these positions.) These results were confirmed by Floyd and Silver (1950) and Lundervold (1951).

These observations suggest that the postural reflex tone subsides or is suppressed for a while in certain circumstances. This happens as mentioned when the possibility exists of obtaining a state of static equilibrium through bony, ligamentous, and capsular support in extreme positions, where active muscle function is not necessary, while, of course, in addition, the passive elastic forces of the extended muscles must be reckoned with. It must be emphasized that this suppression does not last during muscle work with alternating movements.

The question is now what happens to the postural reflexes in standing position and during trunkbending backwards, forwards, and sideways.

The following investigations were, therefore, carried out to illustrate directly the macro-machinery of the human muscles.

For these experiments needle electrodes were preferred to surface electrodes in order to decide if stimulation were present or not. The introduction of the needles causes a little pain, and sometimes a slight activity follows lasting for some few seconds, but soon after quite large movements can be performed painlessly. To avoid pain it is important that the muscle is relaxed during the introduction of the needles, and marked extension of the muscles should also be avoided during the experiments. Very often a standing patient will faint, when he is thus tested, not because of pain, but because of the influence of his surroundings. To avoid this difficulty we used my own back for the experiments, and likewise the backs of some of my assistants and a few brave patients.

At first, it was difficult to interpret the results, but soon some facts emerged concerning the interaction of the muscles. If the muscles of a man standing easy with the feet a little apart (narrow stride-standing position) are tested electromyographically with needle electrodes, no activity is found outside the postural muscles, and even in these only a slight sustained activity appears. In the quadriceps and in the calf muscles there may be no activity at all. In the two erectores spinæ a slight sustained activity is found, most pronounced in the upper thoracic part. (In the levator scapulæ and in the trapezius, in the latissimus and the obliquus externus abdominis a disturbing short, slight activity may be found occasionally during the deepest phase of a deep inspiration when it is on the point of shifting over into expiration.)

The figures show some curves taken from the erector spinæ of a man standing in a narrow stride-standing position during trunkbending backwards and forwards. In order to get a good reproduction, curves were taken from more than one person. Figs. 3, 4, 5 and 9 from Case I. Figs. 6, 7, 10, 11 and 12 from Case II. Fig. 13 from Case I.

This did not of course affect the observations made of the abolition of reflex activity. As was anticipated, the mechanisms of interaction proved much more constant and less complicated in the sagittal plane than in the frontal plane.

A needle electrode was placed in each erector spinæ at the tenth thoracic vertebra.

Trunk-bending backwards may be done in two quite different ways:

Fig. 2 A shows the fundamental position.

Fig. 2 B shows a low slack trunkbending backwards combined with a bending of the knees and an extension of the hips. The movement is initiated from below. The centre of gravity is displaced forwards, *and the patient yields to the new balance.*

Fig. 2 C shows a high trunkbending backwards combined with straightening.

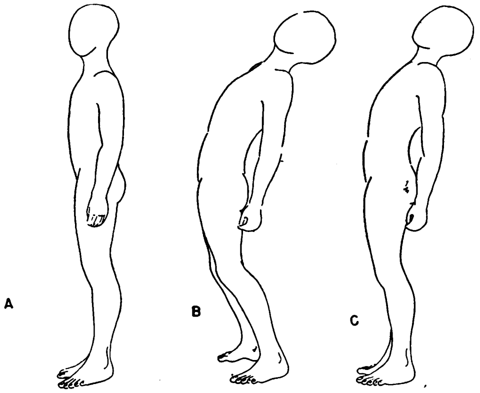

FIG. 2.—A, Normal slack standing. B, Low slack trunkbending backwards. C, Trunkbending backwards.

Fig. 3 shows the curves from a high trunkbending backwards. Electrode a is in the right, and b in the left thoracic part of the erector spinæ. The postural activity is seen, and the activity is raised (A–B and C–D) corresponding to the repeated high trunkbending backwards. The patient does not yield to the new balance, he maintains equilibrium in the position by means of active muscle function.

Fig. 4 shows curves taken in the same starting position with postural activity. By low slack trunkbending backwards (B–C) a complete subsidence of all action potentials takes place. (Only the electrocardiogram persists.) The activity subsides, as soon as the head is inclining, and when the rectus abdominis is extended and brought into play. The bending need not be so deep as shown in Fig. 2 B to make the activity disappear. The main point is that the patient yields to the new balance in hips and knees.

The activity of the erector spinæ reappears, when the patient is asked to return to the original, relaxed standing position. A complete abolition of action potential activity of the postural reflex tone is a fact during low slack trunkbending backwards in spite of the standing position.

Fig. 5 shows the same phenomenon repeated (slack backward bending B–C and D–E). From F trunkbending forwards with raised activity, and still higher activity during erection to the starting position in the last part of F–G. During trunkbending forwards the postural activity is raised through stretch reflexes.

Fig. 6 shows the same phenomenon in another person (Case II) during trunkbending backwards (A–B).

Fig. 7 also shows Case II, A–B during forward bending, B–C during erection, C–D slack standing, D–E slack low trunkbending backwards, all in the standing position.

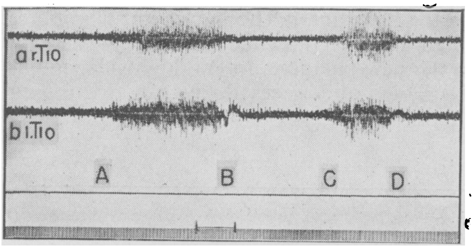

FIG. 3.—a, Right thoracic erector spinæ. b, Left thoracic erector spinæ. Level: Tenth thoracic vertebra. Slack standing position. A–B, C–D, High trunkbending backwards during stretching (Case I).

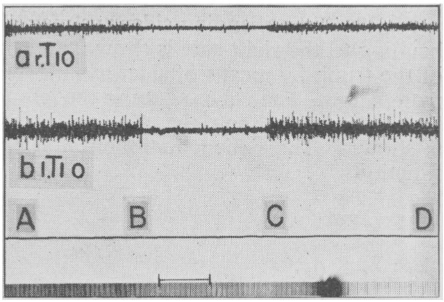

FIG. 4.—a, Right thoracic erector spinæ. b, Left thoracic erector spinæ. Level: Tenth thoracic vertebra. Slack standing position. B–C, Low slack trunkbending backwards. The postural activity subsides. Only electrocardiogram persists (Case I).

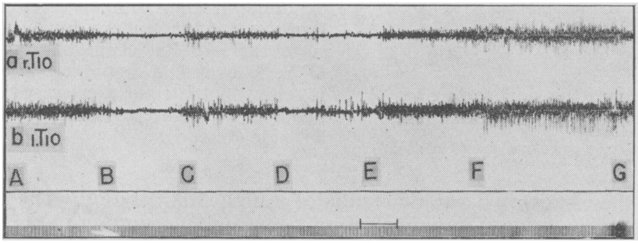

FIG. 5.—a, Right thoracic erector spinæ. b, Left thoracic erector spinæ. Level: Tenth thoracic vertebra. Slack standing position. B–C and D–E repeated, Low slack trunkbending backwards. E–F, Slack standing position. F–G, Forward bending (Case I).

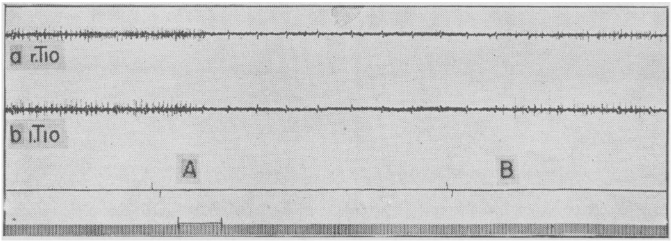

FIG. 6.—a, Right thoracic erector spinæ. b, Left thoracic erector spinæ. Slack standing position. A–B, Slight low trunkbending backwards. The postural activity subsides. Only the electrocardiogram persists (Case II).

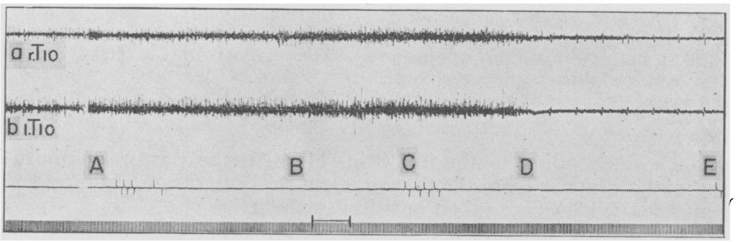

FIG. 7.—Slack standing position. A–B, Trunkbending forwards. B–C, Erection to slack standing position. C–D, Slack standing position. D–E, Low slack trunkbending backwards (Case II).

Fig. 8. Trunkbending sideways may also be done in two ways. In A, a low slack sidebending to the right side is shown, and the sidebending takes place through a displacement of the trunk by means of sideways movements in the hip joints. The movement is initiated from below. The pelvis slides to the left and is tilted to the right, while the trunk is passively bent sideways to the right. The patient yields to the new balance. In B a high sidebending is shown. The patient maintains the positions of hips and knees through active muscle function.

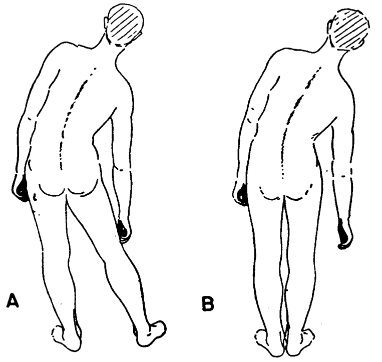

FIG. 8.—A, Low slack sidebending to the right side. B, High sidebending to the right side.

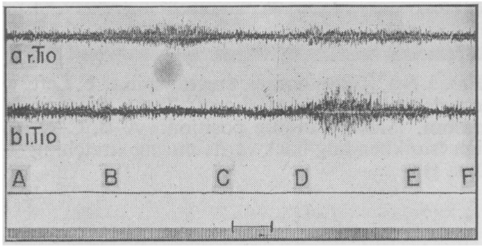

FIG. 9.—Slack standing position. High sidebending. a, Right thoracic erector spinæ. b, Left thoracic erector spinæ. Level: Tenth thoracic vertebra. B–C, Sidebending to the right side. D–E, Sidebending to the left side. The activity is raised in the right erector spinæ during sidebending to the right side, and opposite to the left side (Case I).

Fig. 9 shows the electromyographic results of a high side bending. The starting position is, as usual, a narrow stride-standing position. During sidebending to the right (B–C) the right erector spinæ shows a raised activity; (D–E) during sidebending to the left.

If a low slack sidebending to the right is performed, the postural activity may disappear completely, even in the right erector spinæ, when the extreme position has been reached.

This is shown in Fig. 10 A–B, which was, however, taken in sitting position with one electrode in the thoracic and one in the lumbar part of the right erector spinæ. It may be characterized as a sideways sunken position.

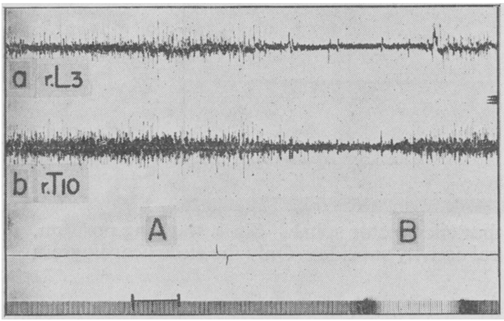

FIG. 10.—*Sitting* erect position. Low slack sidebending. a, Right *lumbar* erector spinæ third lumbar vertebra. b, Right *thoracic* erector spinæ tenth thoracic vertebra. A–B, Sidebending to the right side into a sideways sunken extreme position, where the postural activity subsides almost completely, both in the lumbar and in the thoracic spines (Case II).

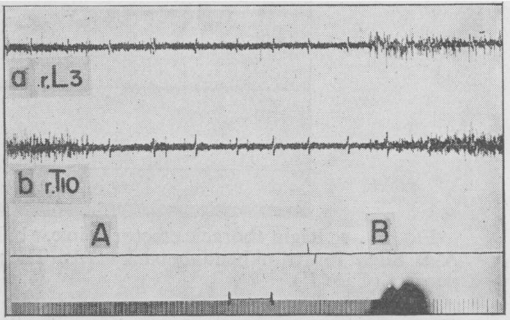

FIG. 11.—*Sitting* erect position. Low slack sidebinding. a, Right *lumbar* erector spinæ. b, Right *thoracic* erector spinæ. Bending sideways to the left side into a complete sideways sunken position. The activity in the right erector spinæ subsides completely during the whole sidebending to the left side from A to B (Case II).

By a low slack sidebending to the left (Fig. 11 A–B) the postural activity in the right erector spinæ may disappear from the first moment, in both the thoracic and in the lumbar part of this muscle. (Sideways sunken position to the left.)

Fig. 12. If the starting position is a standing slight slack trunkbending backwards, the activity subsides as mentioned A–B. From this position a sidebending to the right (B–C) is performed. Through the starting position (C–D) a sidebending to the left side is performed

(D–E). After the starting position has been reassumed (E–F), the patient relaxes into the normal standing position, and postural reflex activity appears in both erectores spinæ (F–G). It can be seen from this figure that in the standing position sidebendings are in this case, performed during almost complete, sustained abolition of the postural activity of the erectores spinæ owing to the simultaneous, slight trunkbending backwards.

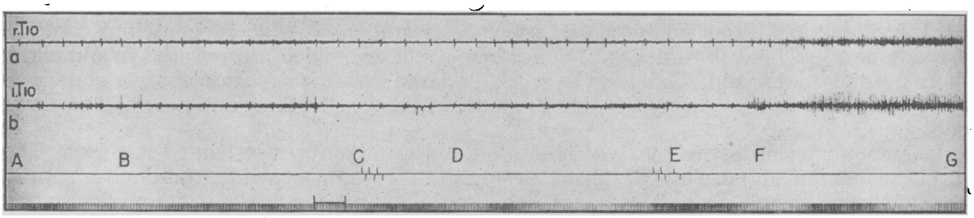

FIG. 12.—a, Right *thoracic* erector spinæ. b, Left *thoracic* erector spinæ. A–B, Low slight slack trunkbending backwards. B–C, Sidebending to the right side. C–D, Reassumption of the starting position in the slight slack low backward bending. D–E, Sidebending to the left side. E–F, Reassumption of the starting position. F–G, Slack standing position. The postural activity is completely suppressed during the low slack backward and sideways bendings (Case II).

It is evident that the technique of bending backwards, forwards, or sideways is quite different when the bendings are performed from sitting position than when they are performed from standing position, because the pelvis is fixed when the patient is sitting down. It is, therefore, much more difficult to carry through a completely relaxed sidebending from the sitting position. On the other hand, it is here less difficult to relax in a forward or in a sideways *sunken* position, that is in extreme positions.

In Fig. 13, the two electrodes are both placed in the right erector spinæ, one in the thoracic, one in the lumbar part. Alternate torsion to the right (A) and left (B) is accompanied by reciprocal function of the two muscle parts here functioning as antagonists.

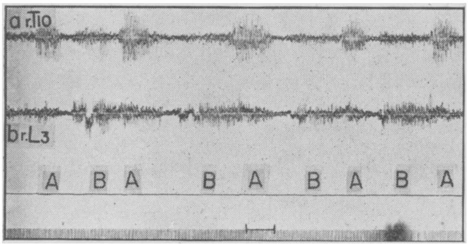

FIG. 13.—Slack standing position. a, Right thoracic erector spinæ tenth thoracic vertebra. b, Right lumbar erector spinæ third lumbar vertebra. A A A A A, Torsions to the right side. B B B B, Torsions to the left side. The thoracic and the lumbar parts of the erector spinæ shown to be antagonists during torsion (Case I).

Experiments in the sitting forward-sunken slack position with lumbar kyphosis confirmed the results of Åkerblom (1948) and Lundervold (1951), that the activity of the lumbar part of the erector spinæ subsided in this extreme position, in spite of the tendency of stretch-reflexes in the erector spinæ during forward bending. Thus it would appear that even the strong postural reflex tone is completely abolished in the extreme forward bent position, in spite of the stretching. This is due to the fact that this position is an extreme position, where capsules, ligaments, joints and passive elastic forces in the muscles are yielding sufficient support. Consequently, postural reflex tone is not necessary in the lumbar part of the erector spinæ. In the upper thoracic part a slight sustained activity persists.

The apparent contradictions of the results determined from patient to patient, and in the same person, are easily explained, when, as here, we consider (1) the different starting positions, (2) the different technique in low and high trunkbending sideways, and in low and high trunkbending backwards and forwards, and (3) the special mechanical conditions in extreme positions with bone and capsule support plus passive elastic forces.

What we had not hitherto realized was that the postural reflexes could be suppressed so completely and so constantly in the standing and sitting positions.

Thus, as part of voluntary movements incurring an active motor stimulation, there is this important feature of the subsidence and abolition of action potential activity of the postural reflex tone.

These experiments seem to prove the reality of a completely local inhibition and an abolition of the postural reflex mechanisms during voluntary muscle work.

If this is right, we may presume a complete inhibition and limitation of the different reflex mechanisms to the extent which is necessary in daily work for its most economical performance. The passive elastic tensions seem to be exploited to the full, and active contractions set in only when necessary. (When this is true of the trunk muscles, it must be even more important in the muscles of the extremities.)

Most of our muscle work is done through interaction between the instinctive and the acquired reflex mechanism with the control of volition superimposed. Postural reflex tone, Magnus and de Kleijn reflexes, grasping reflexes, &c., are built together in a complicated pattern. Volitional and supervised interference is gradually made subconscious through exercise and use, and is turned into conditioned reflexes, which are released in our daily life according to demand. Gait may be reflex, "relaxed" (that is subconscious), or conscious as in the gymnasium or during a military parade, where the stretching and poise are partially conscious.

It is not sufficient just to speak of relaxation and to prescribe a system of exercises. The term "relaxation", so often used during all kinds of musical instruction, training for sports, &c., has got a completely new and unexpected meaning after the demonstration of the effect of the passive elastic forces.

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