INTERACTION BETWEEN ANTAGONIST MUSCLES OF THE HUMAN TRUNK IN RESTING CONDITIONS AND DURING POSTURAL ACTIVITY

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Analysis of the mechanisms of maintenance of the erect position of the human body has revealed one distinctive phenomenon to which attention was drawn by V. S. Farfel'. Whereas in equitonometric conditions of rest [5], the muscles acquire the power of determining the mutual position of the links of the body, in the knee and hip joints a flexor position develops [7].

In Lehmann's investigations [16] the position of rest was determined during a reduction in the weight of the links of the body by immersing it under water. In this case, a flexor position was also discovered in the knee and hip joints. This means that in the erect position stretching of the flexor muscles of the lower limbs takes place and the postural extensor muscles must not only perform their antigravitation function, but must also counteract the pull of the stretched flexor muscles, attempting to shorten. These observations have been extended by the author to the antagonist muscles of the trunk. These investigations are described in the present paper.

If the distal link of a human joint is placed on a readily moveable horizontal area, rotating around a vertical axis, the difference in the tension of the muscle antagonists determines the position of the distal link relative to the stationary proximal link, i.e., the joint angle. At this joint angle the opposite pulls of the antagonist muscles are balanced (equality of the moments of the antagonist muscles) and an equitonometric position arises. Consequently, in equitonometry, the joint angle can be used as an indication of balance of the resting tone of the antagonist muscles of the particular joints.

In the present investigation the equitonometric position of rest was determined for the angle of the trunk.

EXPERIMENTAL METHOD

The trunk equitonometer [6] consists of two parts: a stationary table on which the pelvis and the lower limbs rest, and a horizontal turntable, easily rotating around a vertical axis, attached to the table, on which the upper part of the body is placed. The subject is placed on the apparatus in the lateral position so that the general axis of rotation of the vertebral column (conventionally taken as the joint between the moveable L_5 and the stationary S_1) coincides with the axis of rotation of the moving turntable. In the initial position the trunk angle (the angle between the longitudinal axes of the trunk and pelvis) was 180°, while the angles of the hip and knee joints varied. The platform was then stopped, and the muscles themselves allowed to determine the position of the trunk relative to the pelvis. The electrical activity of the muscles was recorded by means of a Disa electromyograph, using surface electrodes. Altogether 18 adults aged 18-50 years and 20 children aged 8-9 years were investigated.

EXPERIMENTAL RESULTS AND DISCUSSION

The results of many repeated measurements showed that in resting conditions with the subject in the lateral position, the tone of the flexor muscles of the trunk was greater than that of the extensors. This predominance was expressed by the slight angle of forward flexion of the trunk with an initial rectilinear position of the lower limbs (the angle of the hip and knee joints (180°). Experiments with a change in the initial angle of the hip from 180 to 60° showed that this predominance of the muscle tone of the flexors was due mainly to the pull of the ilipsoas muscles. The relationship between the trunk angle and the initial angle of the hip is shown in Fig. 1, from which it is clear that the greatest angle of forward flexion of the trunk was recorded when the initial angle in the hip was 180°. When the angle of the hip was about 120°, the angle of the trunk was 180°, so that with this initial angle in the hip, after removing the stopping device no movement of the platform took place (0 on the axis of abscissas in Fig. 1). With this length of the iliopsoas muscles, the tone of the resting flexor and extensor muscles of the trunk

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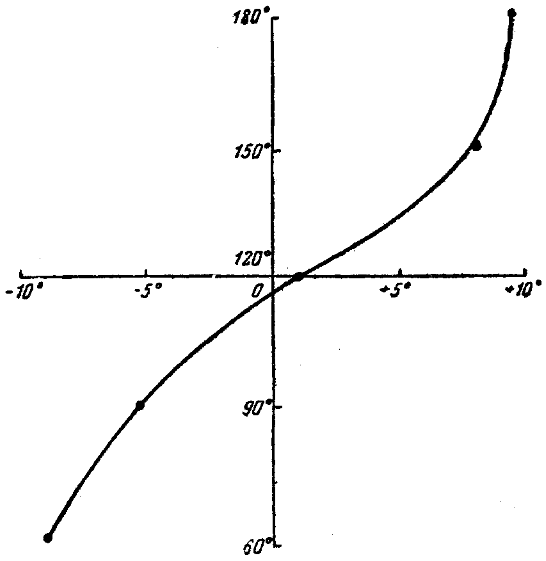

Fig. 1. Relationship between trunk angle and initial angle of the hip. Along the axis of ordinates — angle of the hip; along the axis of abscissas — changes in the trunk angle; +) formed flexion of the trunk; −) extension of the trunk.

was balanced. The angle of 120° may be taken as the resting position for the iliopsoas muscles with the trunk in the erect position (trunk angle 180°).

With a further decrease in the angle of the hip, the tone of the iliopsoas muscles was reduced and was replaced by the stronger pull of the extensors of the spine. This caused extension of the trunk. Consequently, in resting conditions the extensors of the trunk also have a measurable longitudinal tone, although less than the tone of the flexors.

Hence, data obtained by several workers showing that in resting conditions in man the tone in the flexor muscles of the upper and lower limbs is predominant, we must add similar results of observations on the flexor muscles of the trunk. The flexor posture is the normal resting posture in man. We have no grounds for ascribing the predominance of the muscle tone of the flexors over the extensors in the resting position to the "higher degree of tonic excitation of the centers for the flexors over the centers for the extensors" [4], which is the usual explanation of the flexor posture of newborn infants [1, 4]. In the adult person, in resting conditions no electrical activity can be detected in the flexors of the lumbar region of the vertebral column — the abdominal muscles and the iliopsoas muscles [2, 10-12, 17-19]. This applies also to the muscles of the joints of the lower limbs, for which a flexor position of rest has been discovered. Even those investigators who, in some cases, have detected weak electrical activity in the resting muscles have pointed out that the reflex activity is higher in the extensors [3, 8]. Consequently, at rest, the difference in tone of the antagonist muscles in favor of the flexors must be explained by their different elastic pull as "passive" bodies.

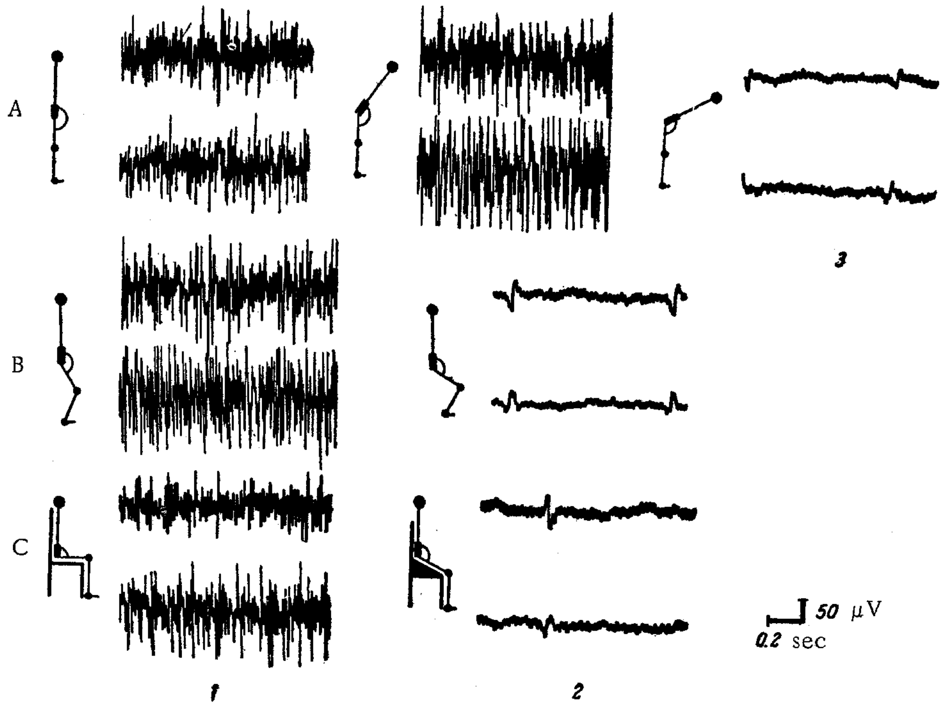

Fig. 2. Electrical activity of the sacrospinalis muscle recorded in the lumbar portion in different positions of the body. A) Standing: 1) angle of hip 180° (initial standing); 2) 150° (trunk inclined forward); 3) 120°; B) standing with hips and knees semiflexed; 1) angle of hip 150°; 2) 120°; C) sitting; 1) angle of hip 90°; 2) 120°. The upper curves for the muscles of the right side of the trunk, the lower for the muscles of the left side. Against the background of the "silent" muscles the peaks of the ECG can be seen.

The results of biomechanical and direct electromyographic investigations [2, 9, 13] show that maintenance of the trunk in man is due mainly to the activity of the extensor group of muscles. At the same time, as equitonometric investigations have shown, in orthostatic conditions stretchning of the flexor muscles and, in particular, of the iliopsoas muscles takes place. If a stretch reflex arises in the stretched flexors, an additional load must be thrown on the extensor muscles. In fact, when standing at ease, weak electrical activity is recorded in the iliopsoas muscles [10, 13].

Stretching of the flexors and, in particular, of the iliopsoas muscles, arising during the change from a resting to an active posture, evidently causes a weak stretch reflex in these muscles, but the activity of the stretch reflex system of the extensors of the spine is increased through the system of intraspinal interaction. This scheme of asymmetric reflex interaction may be postulated on the basis of the results of experiments on spinal cats [15].

The hypothesis expressed above explains the mechanism of the phenomenon of "flexor relaxation" described by Floyd and Silver [13] and repeatedly investigated by Furuno [14]. During considerable forward flexion of the erect trunk, purely as a result of a change in the angle of the hip (Fig. 2A) the electrical activity in the extensors of the spine disappears. The mechanism of this "silence" cannot be explained by a "reaction to lengthening" in response to stretching of the extensors of the spine, for in these circumstances the length of these muscles is bound to change (the erect position of the vertebral column). The inhibition cannot be explained by a reflex influence from the receptors of the stretched ligaments, because this was disproved as a result of experiments on monkeys [17].

The author suggests the following explanation. In the erect position of the trunk stretching of the iliopsoas muscles takes place. This stretching is an essential mechanism of the reflex activation of the extensors of the spine. When the angle of the hip is reduced the iliopsoas muscles shorten. For this reason we can expect that when the resting length for the iliopsoas muscles is reached (when the angle at the hip is about 120°), the activating influence through their receptors on the motor neurons of the extensors of the spine will fall sharply (or cease altogether), leading to "silence" in these muscles. In fact, as Floyd and Silver [12] found, the electrical activity in the iliopsoas muscles disappears when the angle at the hip is that at which "silence" develops in the extensors of the spine. Floyd and Silver do not state the angle at the hip at which this "flexor relaxation" is reached in the muscles of the spine. However, judging by the diagrams in their paper, this angle is close to 120°.

The author suggests that the "silence" in the extensors of the spine may arise in any position when the "resting" length of the iliopsoas muscles is reached. To test this hypothesis two series of investigations were carried out (Fig. 2) in which the electrical activity of the spinal muscles was recorded in different positions of the body. In the investigations of series I (Fig. 2A) a change in the angle at the hip was achieved either in a standing subject during forward flexion of the erect trunk (variant of Floyd and Silver) or as a result of standing with the hip and knee semiflexed (Fig. 2B). In the investigations of series II, the angle at the hip was changed in the sitting position by changing the angle of inclination of the object on which the subject sat (Fig. 2C). In this case the subject also actively maintained the erect position of the trunk (without support from the chair back). In all positions the trunk angle was 180°, i.e., there was no change in the length of the spinal muscles (except in the variant of Floyd and Silver). However, as the electromyograms show, in all variants of the investigations electrical "silence" developed in the spinal muscles when the angle at the hip reached about 120°.

Evidently this hypothetical method of interaction between the flexors and extensors is not confined to the joint of the trunk. In the antagonist muscles of the joints of the human lower limbs (the hip and knee), in which stretching of the flexors also arises in the erect position of the trunk, this asymmetrical reflex interaction is very probable. It is natural to suppose that in every position there are certain parameters for the interaction of the antagonist muscles determined by the position of this and upper joints and by the supraspinal "tuning." The determination of the character of this reflex interaction between the muscles at a joint and between different joints may constitute an essential link in the supraspinal control of postural activity.

SUMMARY

Under the equitonometric conditions of rest, man is found to have a predominance of the muscular tone of the trunk flexors, which is manifested by the anterior bending of the trunk (bending "posture" of rest). This predominance is connected in the main with the resilient traction of the iliac-lumbar muscles. The length of "rest" for the iliac-lumbar muscles is attained at a coaxial angle of about 120° It is presumed that in postural activity the system of reflex to extension of the spine extensors is activated through the receptors of the extended iliac-lumbar muscles. This activating influence is ended upon attainment of the length of "rest" for the iliac-lumbar muscles, i.e., at a coaxial angle of about 120°. This mechanism is used for explaining the electrical silence in the spine extensors oc-

curring in the standing and sitting posture at a coaxial angle of about 120°. A special case is the "flexor relaxation" of the spine muscles described by Floyd and Silver.

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