ON THE RECIPROCAL ACTION OF THE NERVE CENTERS OF THE
MOTOR ANALYSER

E. A. Mukhamedova

From the Department of Physiology, Central Institute for Physical Culture Research,
(Director Assistant Prof. N. G. Ozolin), Moscow

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Academy of Medical Sciences, USSR)

In sports athletes often tense muscle groups which do not directly affect the realization of a movement - tension in the arm, face and neck muscles of a finishing runner, contraction of a skater's arms, joined behind his back, when his foot is raised, change of expression and movement of the head in a tired athlete, etc. Evidently, the inclusion of such "supplementary" muscular groups in the action is one of the factors increasing the efficiency of muscular activity.

The reciprocal action of the nerve centers causing the realization of coordinated movement was first observed by N. E. Vvedensky [2] in a study of the interrelations between the musculatures of animal's legs. N. E. Vvedensky and A. A. Ukhomsky [3, 4] showed that the activity of muscle antagonists is not always opposed but can also be synergistic. The authors point out that the reciprocity of reactions is determined, not beforehand by a predetermined antagonism of the centers, but by the degree of activity in one of the centers, thereby promoting a new functional dynamics principle of reciprocity.

There is cross-innervation in human arms, similar to the cross-coordination found in animal's legs [11, 12], and these functions can also be synergistic [1, 15].

Such a phenomenon of opposite reactions is evidently explained by the different conditions present in the experiments of the various authors, which promoted various types of reaction.

In 1932, I. M. Sechenov [14] showed that efficiency can be more quickly restored to a fatigued right arm when the left arm is in action. Sechenov explained this phenomenon by the fact that "the source of fatigue is not in the muscles, but in the processes occurring in the nerve centers*.

The works of later authors, who studied work and active rest conditions in more detail, [6, 7, 8, 9, 10, 13, 15] show that the effect of a muscular contraction can change depending on the conditions of activity present in other muscular groups.

The purpose of our work was to study the effect of contractions in "supplementary" muscle groups on the efficiency of muscular activity.

EXPERIMENTAL METHODS AND RESULTS

We conducted 5 series of experiments studying the force, speed, duration and frequency of movements in different kinds of muscular activity. The results of several variants of the same simple movement were examined in each experiment.

In the first series of experiments, the maximal muscular tension in "sitting" and "at ease" positions was determined in 41 men by measurement with a hand dynamometer. The tension of muscular groups which did not directly participate in pressing the dynamometer in the "sitting" position, namely, the muscles of the trunk...
and legs, was excluded. In the "at ease" position, the subject pressed the dynamometer in the pose most comfortable to him. The majority of the subjects, in this case, performed a series of movements — the arm was abruptly dropped down from the dynamometer, the subject squatted and inclined the trunk forward. Then the other arm usually became tense and the jaws clenched.

In 95 out of 100 cases, greater muscular force was shown in the "at ease" position, in 4 cases, the results were identical in both positions, and in only one case, greater muscular force was shown in the "sitting" position. The increased force in the "at ease" position was, on the average, 12% as compared with the "sitting" position; individual fluctuations reached 30-40%.

Figure 1 shows the change in the hand dynamometer in one of the subjects.

The force of muscular contraction was studied with an inertia dynamometer in the second series of experiments. The principle of the inertia dynamometer, which was constructed by N. N. Goncharov [5] consists in contrasting the force of inertia with the force of muscular contraction. Flexing the arm at the elbow in the frontal plane with maximal force, the subject stretched the rope, unwinding the discs. According to the speed at which the discs rotated, which was automatically recorded, the force, rate, time and their derivatives — the work and power of the forearm flexion and also the change in these indices during one flexion — could be determined.

When the right forearm was flexed, the force of the muscular contraction was compared with three variants — the left arm relaxed, the left arm simultaneously flexed with a load of 5 kg ("asymmetrical" movement), and the left arm simultaneously extended with a load of 5 kg ("asymmetrical" movement).

A total of 600 movements in 6 men was recorded on the inertia dynamometer. The force of the right arm flexions increased an average of 9% when the left arm was simultaneously flexed. The right arm flexion was not as strong when the left arm was simultaneously extended.

These effects appeared more clearly in work with great resistances (power method). The amount of effort in asymmetrical movements increased from day to day, which did not occur in the contraction of symmetrical muscles (see table).

The example given shows that asymmetrical movement could have a slight positive effect on the very first day in one subject, but a negative effect in another, only gradually, after 5 days, becoming positive. This is explained by the difference in individual abilities to master new movements, which is confirmed by the athletic characteristics of the subjects and by careful and systematic observations made on them.

The other indices of muscular activity also changed depending on the experimental variant. When the left arm performed a symmetrical movement, the speed of right arm flexion increased; the time of flexion decreased in comparison with the first variant, i. e., when the left arm was relaxed.

In the third series of experiments, we studied the effect of left arm muscle contractions during fatigue caused by many repeated flexions of the right arm with maximal force. The subject flexed the right arm at the elbow many times, quickly, and these flexions were recorded on the inertia dynamometer. At different times, the work fatigue of the right arm included the left arm, and the subject continued to flex the right arm while the symmetrical muscles of the left arm contracted simultaneously. In all 5 of the subjects, the effort of the fatigued right arm was raised to the original level or higher by the inclusion of the left arm in the work (Fig. 2). The average increase in effort was 15%, reaching 25-30% in individual movements.

Varying the number of left arm muscular contractions and grouping them in a definite order and time of inclusion, we found certain patterns: the positive effect of including the left arm in the work increased with fatigue; the inclusion of the groups containing 5-8 flexions produced the greatest efficiency; the greatest increase