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Physiological and psychological dynamogenic factors in exercise.

By

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Competitive sports represent a type of activity in which participants endeavor to reach a maximum output of energy. For this reason they undergo a special training regimen which is climaxed by the use of various stimulating means, such as rallies, pep talks and cheers. The men engaged in athletics are constantly searching for some methods which can help them to win a race.

In this connection two questions are of special interest: one of the arm action at the end of the race and the other of a proper pacing.

a. Some years ago track contestants carried in their hands some light object such as cork which they squeezed tightly when approaching the end of the race in the belief that this would help them to run faster. This practice has been discontinued. Now in a long distance race athletes swing their arms in a somewhat relaxed manner, making energetic movements only during the final sprint. Was this use of corks a mere whim or had it any scientific basis even if it were discovered accidentally? Why was it discontinued?

b. In many races some of the runners sprint from the beginning and lead the group for a time, then drop behind and never regain the lead. Usually they are not the best runners. Why do they behave like this? Why should they break their pace? Is this because they lack experience?

The purpose of this article is to attempt to answer these two questions.

I. The hand action.

Historical. Claparède[1] found that when both hands work simultaneously each hand does less work than when they are engaged separately. *Rimathé*[2] verified the above and noticed the same effect when hand and leg were working together. Discontinuation of work by one member always led to an increased output of work by the other. *Rey*[3] observed analogous relationship when he electrically stimulated the arms of a man. He noticed the same reaction experimenting with the hind legs of a guinea pig. *Allers* and *Bierer*[4] found the situation more complicated.

[1] *Claparède:* Arch. Sc. Phys. et Natur. **44**, 71 (1917). — [2] *Rimathé:* Arch. de Psychol. **19**, 128 (1924). — [3] *Rey, A.:* Arch. de Psychol. **23**, 344 (1932). — [4] *Allers, R.* and *J. Bierer:* Arb.physiol. **8**, 490 (1935).

Although in general work done by both hands together was less than the sum of work accomplished by each hand separately, nevertheless there were exceptions to this rule. The investigators also noticed in most of the cases an immediate change in the amplitude of contractions of one hand when the action of the other hand was either commenced or discontinued. The effect was about the same: an increase in one-third and a decrease in one-half of all cases.

Method used in the present investigation. Actual track contests do not lend themselves to this kind of research since there are many factors affecting performance of the athletes which cannot be controlled by the experimenter. Some of these are physiological, some are psychological. Experiments were therefore conducted in the laboratory and the work was measured and recorded by means of an ergograph.

In the course of the present study seven different types of ergographs were used. Various groups of muscles were tested, such as those engaged in abduction and flexion of the index finger, extension of the middle finger, fist clenching and flexion of the forearm and foreleg. The last two groups were found to be more convenient than any of the others, because the amplitude of the movement was so large as to necessitate a great reduction in size of the kymograph tracings. This precluded the possibility of any incidental body jerk mechanically affecting the size of the tracings.

The ergograph used in this study most of the time was attached to the wall. It included two counters; one recorded the number of contractions and the other the sum total of all the tracings. Resistance in the ergograph was obtained by use of either a thirty pound weight or a stiff spring. The kymograph was placed on a shelf above the subject's head, so that he could not see it. A metronome supplied the rythm required, which usually was fifty beats per minute.

The writer has been carrying out these tests since 1932. During the five years of testing, hundreds of curves have been secured of such uniformity that for the past three years this experiment has been used for a routine class demonstration.

The Tests. First Series. The subject was seated with his head and back touching the wall and his right forearm strapped to the lever of the ergograph. The exercise consisted of flexion and extention in the elbow joint, from a vertical position to a maximum possible. When the height of contractions noticeably decreased one of the following procedures was tried (the right arm continuing to contract):

1. Clenching the fist or squeezing a piece of cork in the left hand.
2. Static contraction of the flexors of the left forearm.
3. Flexion and extension of the right forearm.
4. Lifting a 4—20 pound weight using the same movement as in No. 3.
5. Up and down movement of the left leg.

6. Up and down movement of the right leg.
7. Up and down movement of both legs.
8. Cheering.

Second series. The results obtained in the first series were checked by tests of the second series. The subject stood, facing the wall, his left foreleg strapped to the lever of the ergograph so that the flexors of the foreleg were working. The rate of contractions was the same as in the first series. The following tests were tried:

1. Clenching the fist or squeezing a piece of cork in the right hand.
2. Static contraction of the flexors of the right arm.
3. Flexion and extension of the right forearm.

Experimental results. The results of the experiments were strikingly uniform. It was found that when a group of muscles, heretofore idle, was brought into action there was an immediate increase in the height of the contractions of the already working limb which lasted as long as the „idle" muscles continued to work.

Action of the arm or leg, or lifting a light weight, had the same effect. Contraction of both legs, or lifting a heavy weight, had a greater effect. Mere fist clenching had the least effect. Cheering had the most marked effect.

When cheering and a leg or arm action were combined the effect was the same as with cheering alone. When the „idle" limb was exercised with extra vigor the effect was greater than when it was exercised naturally.

It is obvious that the nerve impulses which are necessary for the stimulation of the second group of muscles, in some way reinforce the action of the first group. This is usually a temporary effect. It is also probable that the mechanism of the reinforcement is the same in every case, and the difference of the effect depends only on the difference in the strength of the secondary stimulation. This is supported by the evidence obtained during the weight lifting. When the weight was light, the effect was slight. When the weight was rather considerable (20 pounds or more) the effect was greater, especially during the first two contractions. It is justifiable to conclude that in the latter case the nerve impulses were stronger, and therefore the reinforcement was greater.

In performing these tests special care should be taken to eliminate any factor which may affect the subject, otherwise the results will not be reliable. The following experiment illustrates this.

A subject was working on the arm ergograph. The writer was sitting behind a screen, hidden from the subject yet able to watch him. An assistant was pretending to do some work at a table ten feet away from the ergograph. Occasionally the assistant would rise, walk to the ergograph without paying any attention to the subject and look at the kymograph. Each time he did this the height of the contractions immediately increased. The same thing happened also when the writer rose and looked

at the subject. This explains why some ergograms obtained during a class demonstration were very irregular in their height.

This observation may arouse suspicion as to the validity of the observations obtained. May it not be that the command itself was responsible for the increase in the height of the contractions and not the action of the muscles?

In order to check this several subjects were commanded not to breathe or to open their mouths or close their eyes. In these cases, although the voice used for the command was the same as in the previous experiments, yet the contractions were not at all affected.

II. Remarks concerning pace-breaking in a race.

Competition usually tends to speed up the rate of work. *Moede*[1] showed that in a cancellation test five per cent more letters were crossed out during competition than in individual tests. Good men were either speeded up or slowed down but *poor men were invariably speeded up.*

Observations in the writers laboratory show that in a class demonstration most of the men work harder than when they work alone; and that, when encouragement is given, they tend to increase the rate of contractions.

The same element of competition forces excitable athletes to run faster than they should; hence they tire more quickly, and slacken their speed.

A proper and a sufficiently long training develops on the one hand a greater ability to gauge the speed and the reserve strenght and on the other hand, to produce a greater immunity to the exciting effect of competition.

Conclusions.

1. When a group of muscles is working and another group is set in action there is an immediate increase in the height of contractions of the first group.

2. At the finish of a race a vigorous arm action facilitates the leg action.

3. Squeezing corks or clenching the fists at the end of a race is a helpful device, but is not particularly efficient. A vigorous arm swinging has a greater effect upon the legs.

4. Cheering has a more powerful effect upon the leg contraction than swinging the arms. Yet, in actual competition contestants become relatively deaf and may not be cognizant of such cheering.

5. Excitable athletes under the stress of competition may involuntarily accelerate their pace to excess, thus losing their chance to win a long race[2].

[1] *Moede, W.:* Experimentelle Massepsychologie. 1920.

[2] I want to thank my assistants *Laurence Morehouse* and *Fred Smith* for help rendered during the latter stages of this work.