ON THE REFLEX INFLUENCES FROM THE PROPRIOCEPTORS ON THE HEART

CHANGES IN HEART ACTION WITH THE MULTIPLE APPLICATION OF STATIC LOADS

I. A. Sapov

From the Academy of Navel Medicine (Leningrad)

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At one time we presented facts obtained in experiments on two dogs which indicated the peculiarities of conditioned reflexes formed on the basis of unconditioned reflexes from the proprioceptors on the heart. It was reported that the greatest changes in cardiac action, occurring due to static loading, were observed not while the load was applied, but immediately after the load was removed from the animal's back. The conditioned stimulus caused the following changes in heart action: while a positive conditioned reflex was being developed, the most evident reaction was observed until the 6-10th combination during the period of after-effect also. Beginning with the 7-11th combination, after the conditioned reflex was firmly established, these changes were greatest at the end of the isolated action of the conditioned stimulus. In this case, the so-called static force phenomenon (Lindhardt's phenomenon) which consists of a rise in the functional indicators, in particular of the cardiovascular system, not while work is carried out during static loading, but after it. Lindhardt explained this phenomenon by the constriction by tense muscles of many blood vessels and the encumbered action of the cardiovascular system during static work which develops in connection with this, i.e., he considered a purely mechanical factor to be the reason for this phenomenon. However, N. K. Vereshchagin and his coworkers [1,2,3] showed that this is not quite so, because in the process of training for static work, Lindhardt's phenomenon is smoothed out and the greatest changes in the activity of the cardiovascular system occur during static work, although the action of the mechanical factor remains in force. In the opinion of N. K. Vereshchagin, the static force phenomenon is a consequence of the reaction of the central nervous system to a static load. A. G. Zima [4], studying the dynamics of respiratory movements during static work, also showed that basically, a reflex mechanism lies at the basis of Lindhardt's phenomenon

On this basis, we decided to discover how the static effort phenomenon is evidenced when a static load is applied many times and how it is reproduced by a conditioned reflex method.

EXPERIMENTAL METHODS

The experiments were carried out on two dogs - Jack and Tresor.

The positive conditioned reflexes developed in the animals to a metronome with 120 beats per minute (M_{120}) were again extinguished: several days in succession M_{120} was used once in the experiment without reinforcement. At this, the extinction process of the conditioned reflexes differed little from that observed by us earlier. Then the conditioned reflexes to M_{120} were re-established; one combination of the conditioned and unconditioned stimuli was required for this in both dogs.

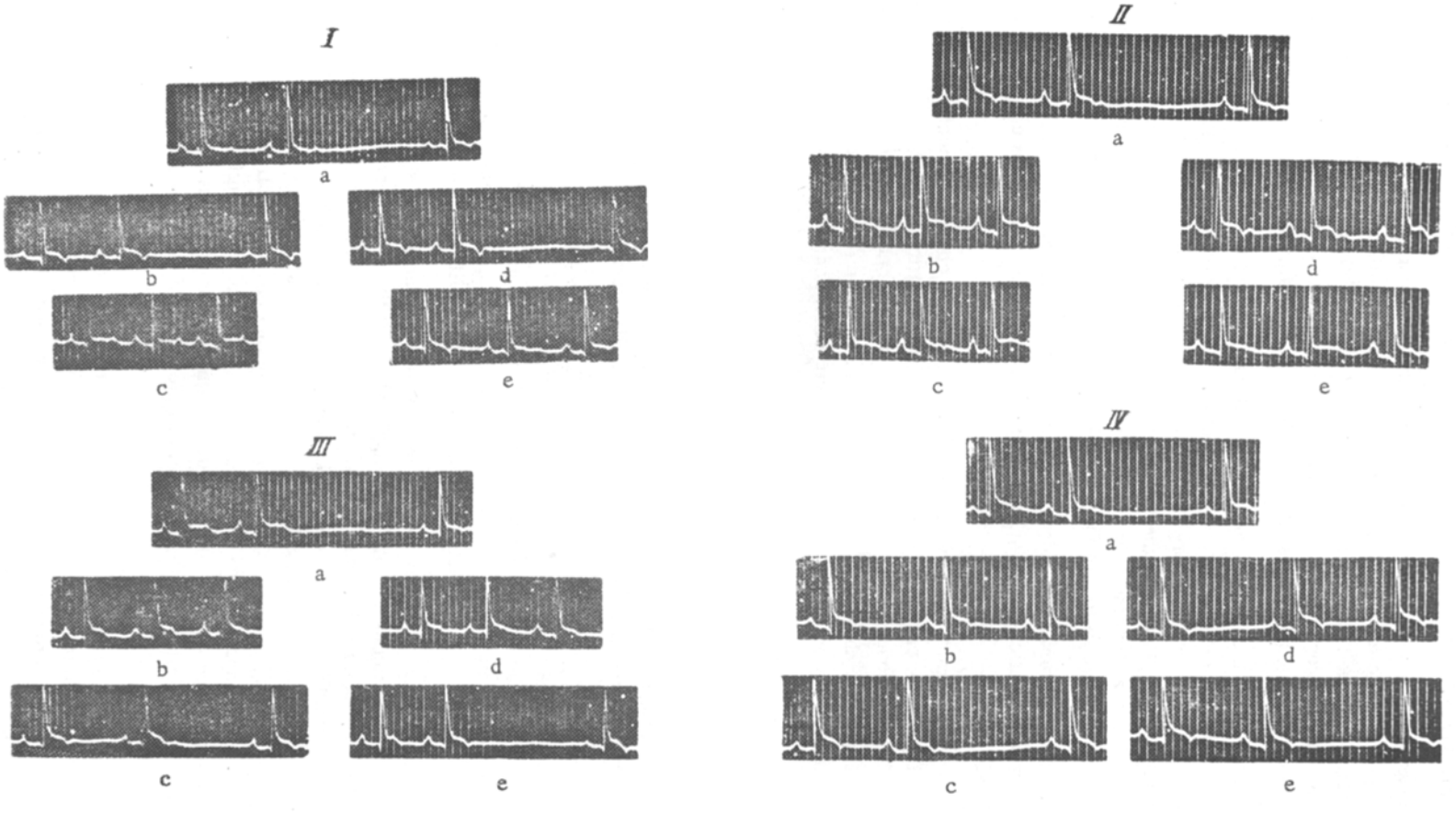

Fig. 1. Phases of the changes in the heart activity of the dog Jack during manyfold applications of stimuli.
I) first; II) second; III) third; IV) fourth. In all groups II EKG lead: a) background, b,c) changes under the influence of the unconditioned stimulus, d,e) under the influence of the conditioned stimulus, during (b and d) and after (c and e) their action.

EXPERIMENTAL RESULTS

As the experiments showed, substantial changes in the activity of the heart occurred with subsequent manyfold combinations of the conditioned stimulus with the unconditioned. These changes are illustrated by the electrocardiograms (Fig. 1) and graphs of the changes of the heart activity (Fig. 2) of the dog Jack.

The first group of electrocardiograms was obtained after the fourth combination of the conditioned and unconditioned stimuli after the re-establishment of the conditioned reflex was begun. The second group of electrocardiograms was obtained after 29 reinforcements of the conditioned stimulus with the unconditioned one. The third group of electrocardiograms was taken from the experiment after the 41st combination of the stimuli. Finally, in the last group are presented the electrocardiograms after 55 combinations of the stimuli.

The evident changes in the activity of the heart which occurred under the influence of the conditioned as well as of the unconditioned stimuli, were characterized by an increase in the frequency of the rhythm, a decrease or disappearance of the respiratory arhythmia, an increase in the height and width of the P wave, an increase in the voltage, a lengthening of the QRS complex, a shortening and an elevation of the R-T segment above the iso-electric line, a decrease in the negative wave T, a decrease in the absolute and increase in the relative duration of the electric systole of the heart ventricles, and an increase in the systolic indicator.

The facts which were obtained in this series of observations indicate that, in the process of manyfold repetitions of the action of static load on animals and of the conditioned stimulus combined with it, four phases of changes in the activity of the heart were observed.

The first phase was characterized by the fact that the greatest changes in heart activity, initiated as a result of the stimulation of the proprioceptors with an unchanging static load, were observed immediately after loading, in the first 30-60 seconds, specifically (static force phenomenon). The second phase was characterized by the initiation of considerable changes in the heart action, not only after static loading, but also during it. The third phase was evidenced by the greatest changes in the activity of the heart, while the animal experienced the action of static loading.

In the fourth phase, it was not possible to note considerable changes in the activity of the heart, neither while the unconditioned stimulus was acting, nor during the period of its after-effect. Now the elevation of the P wave (from 1.6 to 3 mm from the II lead), the decrease of the negative T wave (from 1.4 to 1 mm from the II lead), the voltage increase, the widening of the QRS complex (from 0.06 to 0.07 seconds), the shortening of the R-T interval (from 0.11 to 0.085 seconds) and the decrease in the electrical systole of the ventricles (from 0.22 to 0.20 seconds) became constant, evident both while the stimuli were acting and when they were not applied.

The reaction of the heart to the conditioned stimulus, which was connected with static loading, repeated the reaction of the heart to the unconditioned stimulus. The difference in the dynamics of the changes in heart action in response to the conditioned stimulus consisted in the fact that with the conditioned reflex established these changes preceeded those which were influenced by the unconditioned stimulus.

The phases of the changes in heart activity in response to an unvarying static load and to the conditioned stimulus were observed in the course of manyfold applications of them in experiments on both dogs. They were identical. The difference consisted only in the fact that the change from one phase to another occurred after different numbers of combinations of the conditioned and unconditioned stimuli in the different animals. Thus, the four phases evidenced by the dog Jack were observed (in order) after 4, 29, 41 and 55 combinations, while they were found correspondingly after 6, 36, 46 and 65 combinations of stimuli in the dog Tresor. It should be observed that the number of applications of the static loading and of M_{120} considerably exceeded the indicated number of combinations, since we only indicated the number of combinations applied after the second re-establishment of the conditioned reflexes here. In addition, the effect of the isolated action of static loading on the animals was tested systematically.

Under the influence of systematic manyfold applications of a constant static load, apparently, physical training occurs which leads to the disappearance of any noticeable changes in the heart activity in response to the stimuli which formerly brought them about. It must be assumed that the constant differences between the electrocardiogram elements which occurred as the result of training and those which were observed in the animals at the beginning of the work can be connected with changes in the properties of the heart muscle

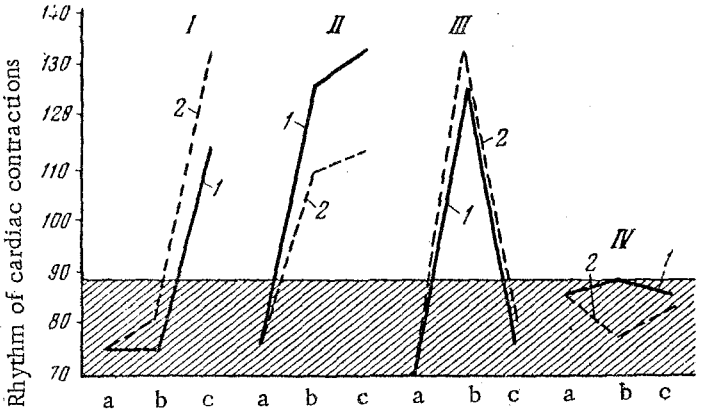

Fig. 2. Dynamics of the changes of the heart activity of the dog Jack during the process of manyfold applications of the stimuli—horizontally.

a) background, b) during stimulation, c) after stimulation .

1) unconditioned stimulus, 2) conditioned stimulus, I, II, III and IV) phases of changes

and, primarily, with changes in the irritability, stimulus conduction and processes of re-establishment [5] which ensure stronger cardiac contractions without noticeable changes in the rhythm and other indicators of the electrocardiogram. As a result of training to static work, the unconditioned, as well as the conditioned stimuli finally became seemingly ineffective on the heart activity, causing no further changes against the new background.

The four phases of changes in heart activity which gradually changed from one to the other are shown during manyfold applications of the stimuli with a constant weight of static load (80% of the animal's weight) and the same duration of action of the stimuli (4 minutes).

Upon changing the intervals of time between the action of the stimuli from 30 seconds to 4 minutes, both with strict coincidence of the conditioned and unconditioned stimuli and with a delay in reinforcement, we could not observe any substantial changes in the heart activity. The unconditioned stimulus of "descent" caused changes in the heart activity characteristic for the given phase, but at the new time intervals, the conditioned stimulus repeated these changes after one combination of the stimuli with the new time relationships.

Changes in the force of the unconditioned stimulus (weight of the static load) affected the heart activity noticeably. This was expressed in the fact that the second and third phases changed into the first phase, i.e., to the emergence of the greatest changes during the period of the after-effect of the stimuli. This was observed in both dogs. In order to illustrate this regularity, the electrocardiograms of the dog Tresor are presented in Fig. 3.

The results of these experiments indicated, first, that after a change in the force of the unconditioned stimulus both in the direction of decrease, as well as in the direction of increase, the changes in the cardiac activity which were observed changed into the first phase, i.e., became characteristic of the initial stage of training; secondly, these changes, when the unconditioned stimulus of the new strength was applied further, quickly returned to the original ones, i.e., to that phase which existed before the size of the static load was changed.

Thus, the static force phenomenon is observed during the first period of training for a static load and is reproduced in a conditioned reflex way. The leveling of Lindhardt's phenomenon in the process of training (as N. K. Vereshchagin also observed), its final disappearance, and, especially, its conditioned reflex reproduction (in our experiments) indicate that it is not the result of mechanical compression of the muscles of the capillaries, but is caused by reflex mechanisms, the initiation of which should be sought in the stimulation of the proprioceptors. The question of whether the the conditioned stimulus causes changes in the cardiac activity directly or whether first it leads to the appearance of muscular contraction and then to the secondary effect—to the change in the cardiac activity, remains not quite clear. Daily observations of the reaction of the animals to conditioned stimuli, combined with static loading, permit the hypothesis that both take place here: at the beginning of

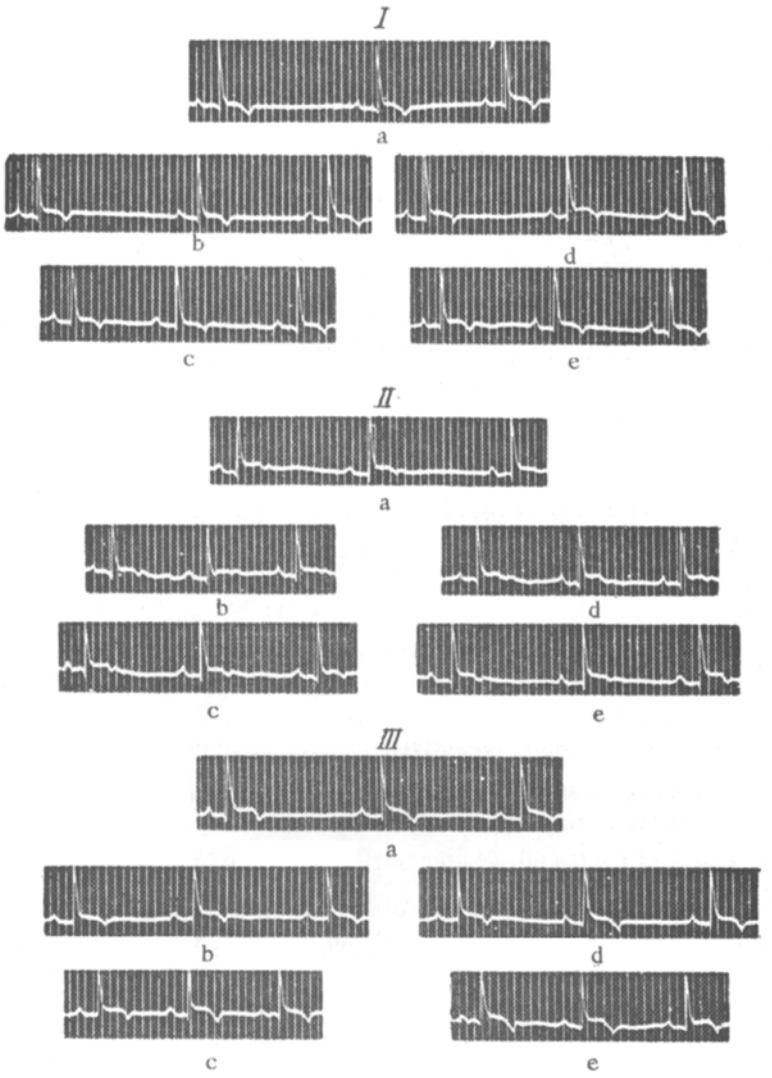

Fig. 3. Effect of changes in the size of static loading on the heart activity of the dog Tresor (EKG lead II).
I) change of the load from 80% to 25% of the animal's body weight, II) after 6 combinations of the new load with the conditioned stimulus, III) change of the load from 25% to 40% of the dog's body weight. In all groups of EKG's: a) background, b and c) changes under the influence of the unconditioned, d and e) of the conditioned stimuli during (b and d) and after (c and e) their action.

training, muscular contraction occurs under the influence of the conditioned stimuli acting alone and secondly (as a reflex from the propriceptors) the change in the cardiac activity occurs, while later changes in cardiac activity occur without the appearance of muscular contraction. This hypothesis requires special verification.

Systematic observation of sportsmen [6] indicates that sports records, for example in short-distance swimming, were obtained not after the usual warm-up, but following the execution of maximum loads by the sportsmen before the meets or during the second start for the same distance. The facts which we presented can indirectly indicate the nature of the phenomenon. We are far from any direct application of the above facts to sports, especially since we observed the training of animals to static loads. Nevertheless, on the basis of the facts obtained, this problem can be subjected to special investigation, suggesting that the changes in the activity of the cardiovascular and other systems of well-trained sportsmen are in the fourth phase and ordinary physical

loads cannot cause substantial changes in the function of their organism. In order that a sportsman at this stage of training should have the ability to carry out maximum work from the start and continue an entire short distance, it is perhaps necessary to provide heavy loads which cause considerable changes in the functioning of the organism during the preparatory exercises (during the warm-up).

SUMMARY

In repeated application on dogs of a constant static load in combination with conditioned stimulus we have observed four stages of changes in the action of heart EKG.

1. In the beginning of training they are best expressed immediately after action of static load (Lindhardt phenomenon).

2. They are equal during and after load.

3. They are noted only during load.

4. No essential changes both during and after load.

All these stages are reproduced by conditioned stimulus. The phenomenon of static effort is caused by reflex influences from proprioreceptors.

LITERATURE CITED

[1] N. K. Vereshchagin, Theory and Practice of Physical Cultures* 1952, vol. 15, issue 8, pp. 565-577.

[2] N. K. Vereshchagin, in the book: Abstracts of Reports of the Scientific Conference on the Physiology of Work,* Moscow, 1953, pp. 29-32.

[3] N. K. Vereshchagin, in the book: Abstracts of Reports of the 8th All-Union Congress of Physiologists, Biochemists, Pharmacologists,* Moscow, 1955, pp. 118-120.

[4] A. G. Zima, in the book: Abstracts of Reports of the Conference on the Problems of the Physiology of Sports,* Leningrad, 1955, pp. 49-50.

[5] S. P. Letunov, Electrocardiography in Medical-Sports Practice,* Moscow, 1950.

[6] A. E. Libel, Theory and Practice of Physical Culture, 1953, vol 16, issue 5-6, pp. 371-376.

[7] I. A. Sapov, Byull. Eksptl. Biol. i Med., 1955, vol. 40, No. 9, pp. 26-30.

* In Russian.