INVESTIGATION OF THE OCULOCARDIAC REFLEX AT VARIOUS MOMENTS DURING STATIC MUSCULAR EFFORT

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During static muscular effort many conditioned and unconditioned reflexes are depressed, and as a result it has been suggested that a process of inhibition predominates in the central system at this time. However, it is usually the positive reflexes that are investigated during static muscular effort, and the question arises, how are the inhibitory, and not the positive reflexes modified by the influence of static muscular effort. We met with this problem in particular when studying the secretion of gastric juice in response to milk [2]. If in the milk experiments static muscular effort was applied during the first hour of secretion, the volume of juice produced during this hour was increased, i.e., the secretory process, inhibited by the reflex influence of the milk fat, was disinhibited. In the present investigation, as an inhibitory reflex we studied Aschner's oculocardiac reflex—the slowing of the heart beat in response to pressure on the eyeballs.

EXPERIMENTAL METHOD

The investigations were conducted on 53 young, healthy human subjects. Presssure on the eyeballs was applied by means of two Marey's capsules, fixed in a special binder, and connected to a manometer. To elicit Aschner's reflex, the pressure in the capsules was rapidly (in the course of 1-2 seconds) raised to 100-110 mm Hg and maintained at that level for 8-9 seconds. From 2 to 3 minutes before pressure was applied to the eyes, during and after the application, the rate of the heart beat was recorded every 10 seconds without interruption. To record the pulse continuously, a cuff was applied to the subject's forearm, and the pressure inside it was raised approximately to the mean pressure in the arteries of the forearm. The variations in the pressure inside the cuff caused by the pulse movements of the arterial walls were recorded by means of pneumatic transmission on a kymograph for 15-25 minutes. During this period Aschner's reflex was elicited several times at intervals of 3-5 minutes (before, during, and after static muscular effort). After the experiment the number of pulse beats in each 10 seconds was counted and a curve of the pulse rate was constructed. Portions of these curves are shown in Figs. 1 and 2. The magnitude of the Aschner's reflex was expressed as a percentage giving the slowing of the heart rate in proportion to the original rate. The investigation of the oculocardiac reflex at rest and during muscular effort was conducted in three main variants of the experiments. The first variant, on 24 subjects, the static muscular effort consisted of squeezing the bulb of a Rozenblat's dynamometer with the free hand to $\frac{1}{4}$ strength; in the second variant the static effort consisted of holding a weight equal to half the subject's body weight on his shoulders (11 subjects); in the third variant a weight of 9 kg was held in the lowered, outstretched hand (7 subjects). The static effort was discontinued when the subject showed marked fatigue.

EXPERIMENTAL RESULTS

The oculocardiac reflex was sufficiently well marked in only 53 of the 60 subjects, and in the other 7 it was either hardly detectable or took the form of an increase in the heart rate. These 7 subjects took no further part in our experiments. The magnitude of Aschner's reflex in our subjects in a resting state usually varied from -8 to -15%; the maximal value of the reflex was -27% and the minimal -5%. The greatest slowing of the pulse took place either during pressure on the eyes or 10-30 seconds afterwards.

Control experiments showed that the first application of pressure to the eyeballs very frequently gave a more marked effect than all the rest, which stayed at approximately the same level with slight deviations to either side. We accordingly determined the magnitude of the reflex in all the investigations twice before muscular effort, and

used only the second reflex for comparison with the findings during effort. During static muscular effort, in each subject we usually made two determinations of the magnitude of the reflex. In some subjects this was at the first minute of effort and at its end, and in others it was in the middle of the period of effort or after its discontinuation. Some determinations of the magnitude of Aschner's reflex could not be utilized when the results were analyzed, because the background pattern of the cardiac contractions was very unstable directly before pressure was exerted on the eyeballs.

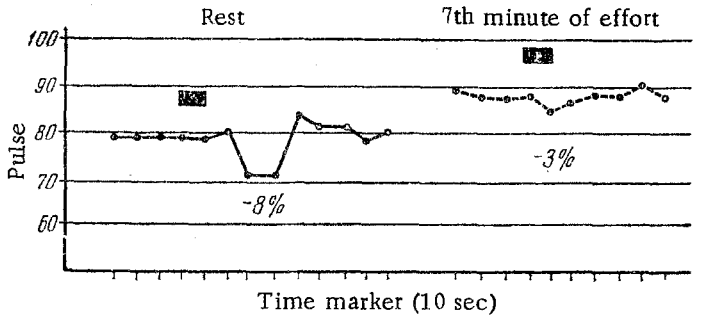

Fig. 1. Decrease in the magnitude of Aschner's oculocardiac re-reflex at the 6th minute of static muscular effort (holding a weight on the shoulders). The black rectangle denotes the time of application of pressure to the eyeballs; the figures denote the magnitude of the reflex.

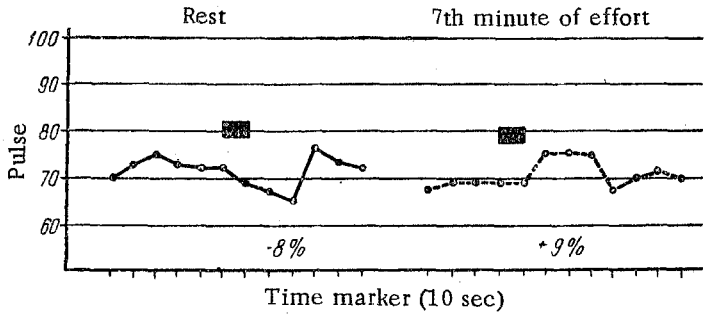

Fig. 2. Reversal of Aschner's oculocardiac reflex during static muscular effort when the subject felt fatigued (carrying a weight on his shoulders). Legend as in Fig. 1.

In all three series of our experiments, irrespective of which muscle groups took part in the static effort, identical results were obtained. At the beginning of muscular effort, during the first 30 seconds, the magnitude of the reflex as a rule decreased (see Table 1). If the oculocardiac reflex was reproduced at the second minute of muscular effort, the inhibition of the cardiac contractions was more marked than in the resting state. Repetition of the test subsequently, just before the end of effort showed that in most cases a phase of reduction in the depth of the reflex reappeared (see Fig. 1). This phase was the most stable and prolonged, for the preceding phase passed off quickly and was not found at all in some subjects.

It follows from what has been said that the changes in the oculocardiac reflex during static muscular effort occurred in several phases. Basically, however, during effort, apart from its first minutes, the excitability of the centers of the vagus nerves was lowered. We consider that the occurrence of these phases may be correlated with the scheme of phases of cortical states during static effort suggested by N. K. Vereshchagin [1].

At the very beginning of muscular effort (the trigger period, in Vereshchagin's terminology) a process of inhibition spreads throughout the cerebral cortex, orginating along the lines of external inhibition as a result of the action of a new stimulus—effort. In our case this was expressed as a decrease in the magnitude of the, reflex, for

the excitability of many nerve centers, including those of the vagus nerves, was lowered. Subsequently, during the first few minutes of static muscular effort, when the excitation in the zone of the motor analyzer was still inadequately concentrated, it irradiated and so increased the excitability of several nerve centers, including the centers regulating the tone of the parasympathetic nerve centers (the phase of irradiation of excitation). Consequently, the heart rate was slowed to a greater degree than in the resting state. As the static muscular effort continued, with the increasing concentration of excitation in the nerve cells of the motor analyzer, a zone of negative induction was created around this focus of excitation, lowering the excitability of the parasympathetic nerve centers. The reaction of these centers to stimulation was thereby decreased (the phase of induced changes, in Vereshchagin's terminology). After the end of static muscular effort, the vagus nerve centers remained a short time (about 1 minute longer) in a state of lowered excitability, after which their excitability again increased as a result of successive positive induction and the oculocardiac reflex was more marked than in the state of rest. In some cases, in the last minutes of static muscular effort, when the subjects were feeling considerably fatigued, we observed a reversal of the reflex and the heart rate became faster (see Fig. 2). We sometimes observed the same phenomenon at the second minute after effort.

TABLE 1. Changes in the Magnitude of Aschner's Reflex During and After Static Muscular Effort

Moment of investigation	Variant	Results of each variant: No. of investigations	No. of these with: Decreased reflex	No change	Increased reflex	Combined results of all variants: No. of investigations	No. of these with: Decreased reflex	No change	Increased reflex
During effort									
Beginning of first min	First	6	4	2	–	7	5	2	–
	Second	–	–	–	–				
	Third	1	1	–	–				
End of first min	First	6	–	2	4	15	2	6	7
	Second	3	–	2	1				
	Third	6	2	2	2				
Second min	First	6	1	1	4	13	2	3	8
	Second	7	1	2	4				
	Third	–	–	–	–				
Third min and later, to the end of effort	First	10	6	3	1	27	19	5	3
	Second	10	8	1	1				
	Third	7	5	1	1				
After effort									
First min	First	14	8	4	2	20	12	6	2
	Second	2	–	2	–				
	Third	4	4	–	–				
Second min	First	–	–	–	–	5	–	1	4
	Second	4	–	1	3				
	Third	1	–	–	1				

An additional series of experiments was carried out on 11 subjects, when the oculocardiac reflex was investigated during a period of submaximal static muscular effort (squeezing the bulb of a Rozenblat's dynamometer with the hand to 10-15 mm Hg below the maximal strength). This muscular effort could be continued for 30-40 seconds. After 20 seconds we investigated the oculocardiac reflex and compared its magnitude with its background level.. In 4 subjects pressure on the eyes in these conditions caused no reaction, and in two the reflex was reversed, while in the rest it was considerably decreased.

The inhibitory oculocardiac reflex is thus modified during static muscular effort. These changes occur in phases, the most stable and prolonged of which is the phase of decreased magnitude of the reflex, indicating the predominance of a process of inhibition in the higher divisions of the central nervous system during static muscular effort (except the motor analyzer). This conclusion agrees with our results obtained in dogs when studying the secretion of gastric juice in response to milk, and it confirms the hypothesis that the leading part in the changes in the activity of the internal organs occurring during static effort is played by reflex mechanisms.

SUMMARY

Oculocardiac Aschner's reflex undergoes phasic changes during static muscular efforts. The main and the most stable and prolonged is the phase of decreased reflex strength (reduction of the inhibitory effect on the rhythm of the cardiac contraction), pointing to the prevalence of the inhibitory process in the higher portions of the central nervous system during static muscular efforts. This confirms the suggestion that the main role in the changes occurring in the activity of internal organs during static efforts belongs to reflex mechanisms.

LITERATURE CITED

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