CHANGES IN RESPIRATION FOLLOWING VOLUNTARY HYPERVENTILATION

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It has been established that the changes in respiration that occur following hyperventilation are caused by a complex of different factors. These include both neuroreflex and humoral influences. A detailed survey of the respiratory changes produced by hyperventilation can be found in the literature [1, 2, 3, 7, 8].

In the present investigation we have studied the effect of hyperventilation on subsequent respiration in athletes in different stages of training.

METHODS AND RESULTS

The usual pneumographic methods were used in these experiments. We examined 148 athletes having various specialties and skills, as well as 26 persons not engaged in athletics.

Experiments with repeated tests of hyperventilation for various periods (10, 25, and 40 inspirations and expirations, each having a volume of 70-83% of vital capacity, for 20, 50, and 80 seconds) showed that the character of the respiratory changes that ensue in athletes does not depend on the time of day (experiments were carried out between 7 AM and 11 PM), and does not change over a period of 3-4 days.

Experiments with these tests on 68 athletes in different stages of training gave the following results. In 35 subjects the character of respiration before, during, and after hyperventilation was comparatively uniform, both when they were in poor training and when they were in excellent training. In the other athletes, various changes were seen. Thus, during the period of hyperventilation in 25 persons at an early stage of training, we noted interrupted respiratory cycles and a variable amplitude, which decreased toward the end of the test. In the same individuals, changes in amplitude and arrythmia of respiratory movements were observed after hyperventilation, as well as periodic breathing. When these individuals reached excellent condition, the phenomena just described either stopped or became less pronounced. In eight athletes, hyperventilation produced inhibition of the activity of the respiratory center in an early stage of training, which was replaced by elevation of the activity of this center when the subjects were in condition (Fig. 1).

In the great majority of the athletes, we failed to observe apnea after hyperventilation.

In the light of this fact we examined 26 persons not engaged in sports. No noticeable differences were found between the character of post-ventilation breathing in athletes and nonathletes. Various types were found in both groups; the most characteristic of these are shown in Fig. 2.

The first type is distinguished by the fact that hyperventilation has no noticeable effect on respiration. The characteristic of the second type is an increase in the rate and depth of respiration after hyperventilation, as compared with the initial state. The third type characteristically develops periodic respiration, and the fourth type, prolonged apnea.

The first two types and their varieties were encountered among 76% of the subjects (athletes and nonathletes). The last two types were found in 24% of the subjects, with apnea after hyperventilation being observed in some individuals only at an early stage of training. "Pure" apnea was observed in only eight persons, two of whom had studied physiology and knew that hyperventilation "is invariably followed by apnea." Apnea was noted after hyperventilation of 10 or more respiratory cycles. The duration of the apnea was found to be directly related to the duration of hyperventilation, which is in agreement with available data [5].

We conducted separate experiments with 18 students who were given the following six tasks at intervals of 3-6 minutes: 1) a bell rang (50-120 seconds), and the subject was asked to determine how long it rang; 2) the subject was ordered to read 1-1½ pages of a popular text in 60-80 seconds and recall correctly what he had read; 3) hyperventilation was performed at the command of the experimenter (25 cycles in 50 seconds); 4) the task was the same as the previous one, but the first task given at the end of hyperventilation; 5) the same, but followed by the second task; 6) control hyperventilation.

The first and second tasks usually had no noticeable effect on respiration (Fig. 3). After the third task, respiration either increased in intensity or remained essentially unchanged, in most cases.

During the fourth and fifth tasks, the first and second indifferent stimuli usually had an inhibitory effect on respiration. We observed this in 10 out of 18 subjects. In

* Deceased.

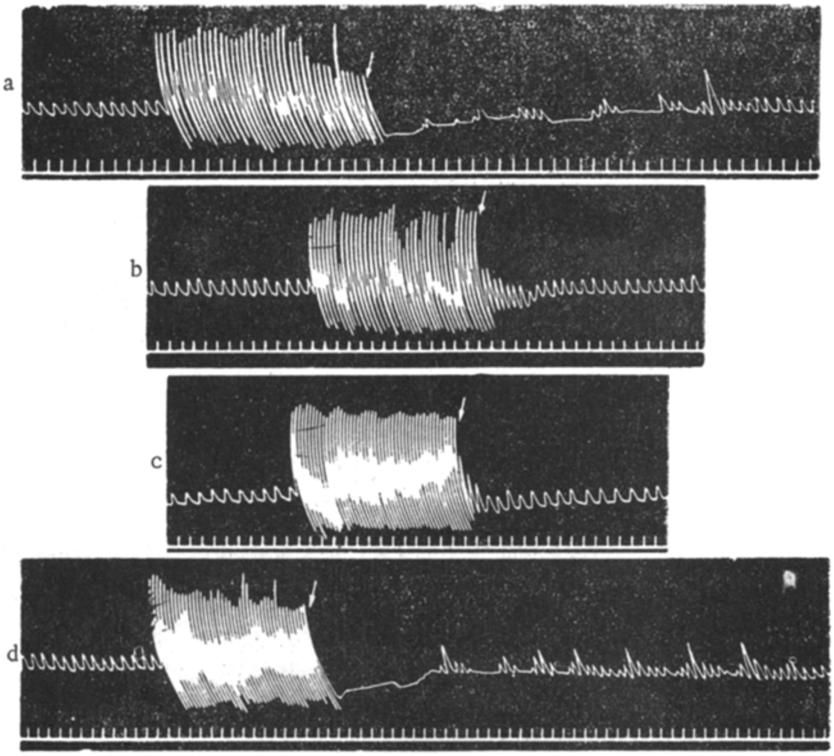

Fig. 1. Effect of hyperventilation on respiratory changes in athletes at various stages of training. Pneumograms recorded: a) in March, 1952 (early stage of training); b) in December, 1952 (halfway through training); c) in April, 1953 (in shape for competition); d) in September, 1953 (out of training). Interpretation of records (from top down): pneumogram; time (5 sec); (subject St-v, athlete of the first class, light heavyweight, 20 years old).

four subjects, respiration was inhibited during only one of the tasks (the fourth or fifth); and in four others, the character of respiration after hyperventilation during the fourth and fifth tasks was no different from that during the third and sixth tasks.

Our data permit us to suppose that in the complex network of nervous and humoral factors under whose influence the reaction of the respiratory center to hyperventilation develops, cortical influences are of great importance.

Excitation that has developed in the motor zone of the cortex during voluntary hyperventilation, upon irradiating to subcortical nuclei and the brain stem, can in many instances cause the rate and depth of respiration to increase for a period of time, as we and other authors have observed [1, 6, 9]. It ought to be noted particularly that in this case the rate of respiration is often close to the rate of respiration in hyperventilation. These observations can be explained by an Ukhtomskii-type assimilation of rhythm (the possibility of assimilation of rhythm by the respiratory center has been shown by E. B. Sologub [4]).

Cortical influences on respiration after hyperventilation are evidently the controlling factors, since in 365 out of 593 cases the rate of respiration increased after hyperventilation (in 228 cases it remained unchanged or became somewhat slower, or the third and fourth types of respiration were observed).

The inhibitory effect of humoral factors became dominant during the execution of the fourth and fifth tasks. In these cases, normally indifferent agents apparently created new foci of excitation in the cortex, inhibiting cortical stimulation of the medullary respiratory center, and the humoral factors came into their own.

SUMMARY

The following types of respiration were observed in 148 athletes and 26 nonathletes after voluntary hyperventilation: 1) ordinary respiration; 2) respiration of increased rate and depth; 3) periodic respiration; and 4) apnea. The first two types were seen in 76% of the persons examined, and the last two in 24%. The incidence of the first two types increases in athletes as training progresses.

The changes that occur in respiration after hyperventilation are caused by a complex of nervous and humoral factors that result in enhanced respiration.

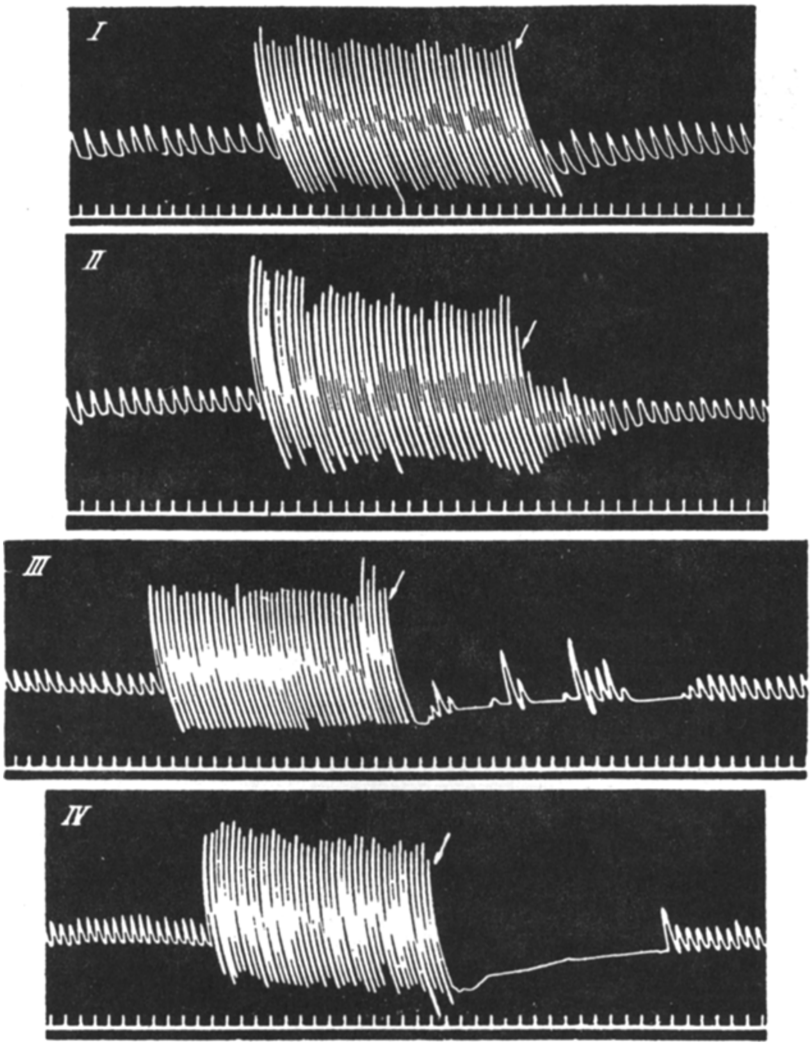

Fig. 2. Various types (I, II, III, IV) of respiratory change following hyperventilation. Interpretation of curves is the same as in Fig. 1.

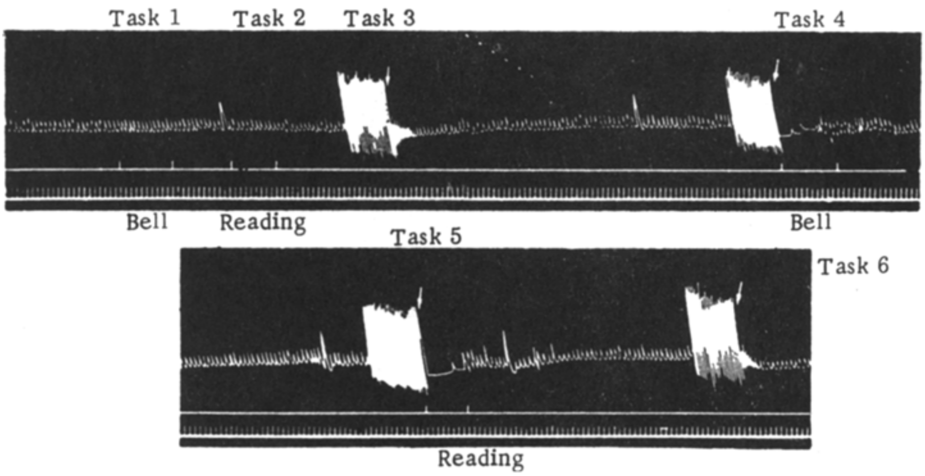

Fig. 3. Respiratory changes following hyperventilation (subject N.). Interpretation of curves is the same as in Fig. 1.

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