

# ELECTRICAL ACTIVITY OF THE HUMAN RESPIRATORY MUSCLES DURING THE ACTION OF VARIOUS HUMORAL INFLUENCES ON THE RESPIRATORY CENTER

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Many investigators [3,4] have used microelectrode technique to stimulate single cells of the respiratory center, and have picked up potentials from single points in order to determine precisely the localization of the inspiratory and expiratory zones; they have concluded that in the respiratory center of the medulla there are separate inspiratory and expiratory neurones. The only difference of opinion concerns the topography of the inspiratory and expiratory zones. M. A. Mislavskii's views [2] on the respiratory center have therefore been confirmed. However, until now the nature of the relationship between the inspiratory and expiratory neurones has remained unexplained.

By varying the oxygen tension in the arterial blood, Baumgarten [3] found that there was a reciprocal relationship between the inspiratory and expiratory neurones of the reticular formation of the medulla. In acute experiments on cats under conditions of hypoxia, hyperoxia, and hypercapnia, M. E. Marshak discovered the same kind of reciprocal relationship between the inspiratory and expiratory muscles and nerves [1].

To determine the functional relationship between the inspiratory and expiratory zones of the respiratory center in man, we have made a study of the changes in the electrical activity of the inspiratory and expiratory muscles during changes of the oxygen and carbon dioxide tensions of the arterial blood.

## METHOD

The observations were made on three subjects aged 22-24 years, who lay supine. Action potentials were picked up from surface electrodes; connection was made to the inspiratory muscles by attaching the plates to the 7th intercostal space and to a point to the right of the xiphoid process, and for the expiratory muscles the plates were fixed to the external oblique muscle of the belly, and recording was made by a DISA electromyograph.

With normal respiration the action potentials collected from the surface electrodes were very weak: during inspiration the potentials were between 10 and 20  $\mu$ V, and with the amplification we used, this amount was scarcely noticeable. It was essential to make arrangements so that at rest the activity of the respiratory muscles should be greater than under conditions of normal breathing. We therefore established an additional resistance to inspiration (by means of Muller's water valves), the height of the water column being 50 mm. With the added resistance there is a reflex excitation of the respiratory center which leads to an increased activity and an increased number of impulses in the respiratory muscles.

The subjects were adapted to these conditions by breathing in this way 3-4 times per week for one month. During this time the electrical activity of the respiratory muscles became adapted to the conditions, and stabilized.

Besides recording the action potentials of the inspiratory and expiratory muscles, we studied pulmonary ventilation, breathing rate, and alterations of the arterial blood oxygen saturation.

## RESULTS

While a trained subject breathed against the added resistance for 6, 8, or 10 minutes, a gaseous mixture containing 9% oxygen was substituted for normal air. The arterial blood oxygen saturation then fell to 80-85%. The respiration rate was slowed, but breathing became deeper, and pulmonary ventilation rose above the previous level.

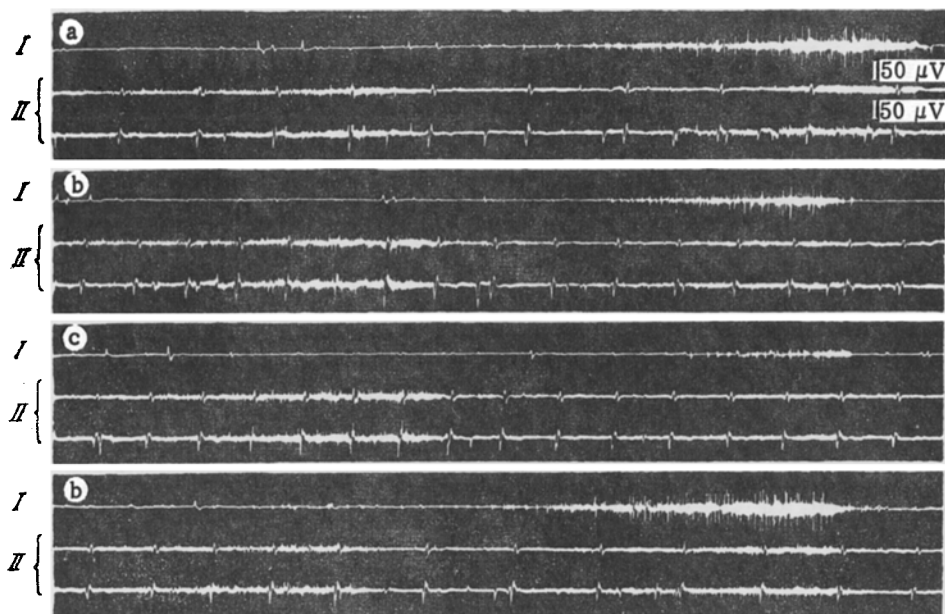


Fig. 1. Electromyograms (I) of the expiratory and (II) inspiratory muscles during breathing against an added resistance (subject M). a) Air; b) after 5 min; c) after 7 min breathing a gaseous mixture containing 9% oxygen; d) air.

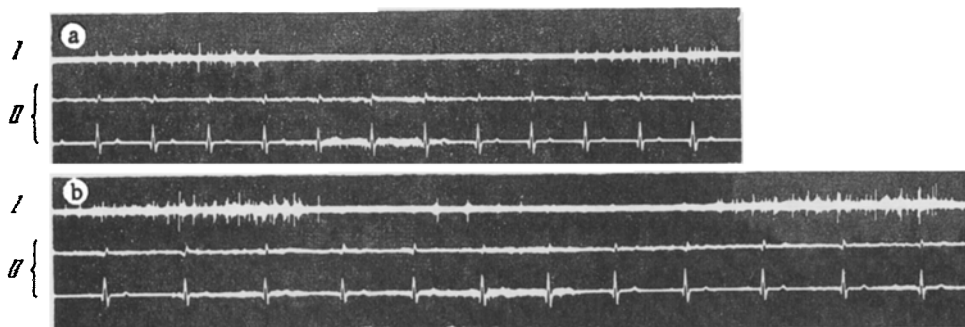


Fig. 2. Electromyograms of (I) the expiratory and (II) the inspiratory muscles during breathing against an added resistance (subject P). a) 5 min 30 sec after breathing a gaseous mixture containing 9% oxygen; b) pure oxygen.

During respiration of the hypoxic mixture, the electrical activity was enhanced: there was an increase in the amplitude of the action potentials and of the duration of the inspiratory phase; during expiration, the electrical activity of the expiratory muscles fell, and the amplitude and frequency of the action potentials was reduced. The level of electrical activity of the inspiratory and expiratory muscles recovered rapidly to the original value as soon as the subject changed over to breathing atmospheric air (Fig. 1).

In some experiments, after the hypoxia, the subject changed over to breathing pure oxygen. Then at inspiration there was a reduction in the activity of the inspiratory muscles, and an increased activity of the expiratory muscles at expiration (Fig. 2).

In the second set of experiments, while the subject breathed against the added resistance, the air supplied contained an increased amount of  $\text{CO}_2$  (5%), and was given for 6, 8, or 10 min.

During hypercapnia, just as in hypoxia, there was an increased electrical activity of the inspiratory muscles; there was a marked increase in the amplitude of the action potentials, and the inspiratory phase was prolonged.

During expiration, the electrical activity of the expiratory muscles fell to such an extent that the electrical impulses recorded could barely be distinguished. Here, evidently, expiration was brought about by passive collapse of

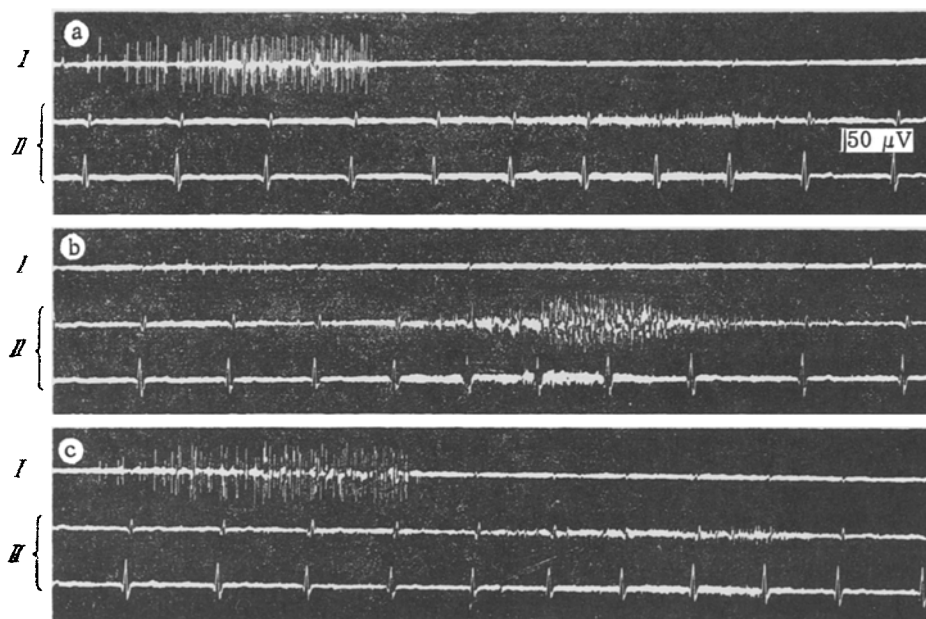


Fig. 3. Electromyograms (I) of the expiratory and (II) of the inspiratory muscles during respiration against an added resistance (subject P). a) Air; b) gaseous mixture containing 5% carbon dioxide; c) air.

the thorax. As soon as the subject changed over to breathing atmospheric air, the electrical activity of both groups of muscles recovered to the original level (Fig. 3).

Thus, the reduction of the oxygen tension increases the activity of the inspiratory center; the result is an increase in the flow of impulses to the inspiratory muscles, whose electrical activity becomes markedly enhanced. The increased activity of the inspiratory center in hypoxic hypoxia inhibits the expiratory center, with the result that the electrical activity of the expiratory muscles falls. On the other hand, an increased arterial blood oxygen tension increases the activity of the expiratory center and enhances that of the expiratory muscles. The increased activity of the expiratory center in hyperoxia inhibits the activity of the inspiratory center and reduces the activity of the inspiratory muscles.

Hypercapnia has the same effect on the electrical activity of both sets of muscles as does hypoxic hypoxia.

These results are in agreement with those obtained by M. E. Marshak [1] in acute experiments on cats, and demonstrate that in man there is a complex reciprocal relationship between the expiratory and inspiratory zones.

#### SUMMARY

The electrical activity of human inspiratory and expiratory muscles was studied in hypoxia, hyperoxia, and hypercapnia during added resistance to respiration. The results obtained confirmed that in man the inspiratory and expiratory zones are reciprocally related. This condition was distinctly demonstrated during changes of the arterial blood oxygen and carbon dioxide tensions. In hypoxic hypoxia and hypercapnia electrical activity of the inspiratory muscles was enhanced, and that of the expiratory muscles reduced. The reverse effect was obtained during the inhalation of pure oxygen.

#### LITERATURE CITED

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. Some or all of this periodical literature may well be available in English translation. A complete list of the cover-to-cover English translations appears at the back of this issue.

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