

CHANGES IN LUNG VOLUMES AND VENTILATION IN HEALTHY AND SICK PERSONS DURING HYPOXIA

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Most investigators have found that during hypoxia the vital capacity of the lungs (VC) is reduced, while the pulmonary ventilation is increased [1, 3, 4, 8, 9]. Little work has been done on the study of the changes in external respiration during the action of hypoxia in persons with various disturbances of function. We have studied the external respiration in subjects in a pressure chamber in conditions equivalent to an altitude of 5000 m and also when breathing a mixture of nitrogen with 11% oxygen at the normal atmospheric pressure.

EXPERIMENTAL METHOD

Dry gas meters were used, in combination with the KM-16 mask, the expiratory valve which was joined to the meter, a universal spiograph, and a metabolic spiograph. Altogether 203 investigations were made. Depending on their state of health the subjects were distributed among the following groups: healthy—78 persons, patients with initial forms of hypertension and atherosclerosis—32, patients with residual manifestations of pulmonary tuberculosis—28, patients with autonomic vascular dystonia—13, and patients with other diseases—12. The ages of the subjects ranged from 25-40 years. The numerical results were treated statistically.

EXPERIMENTAL RESULTS

Contrary to data described in the literature, no significant decrease was found in the VC in the presence of a high resistance to hypoxia, which contradicts V. A. Gamburtsev's idea [4] that there is a marked reduction in the tone of the respiratory muscles in these conditions. A considerable decrease in the VC was usually observed only when the resistance to hypoxia was lowered to a marked degree.

Moderate changes took place in the complemental and supplemental air volumes. The tidal air usually showed a clear increase both at an "altitude" of 5000 m and during inhalation of the hypoxic mixture. The inspiratory volume increased on account of an increase in the tidal air.

When the subjects possessed some impairment of function, and especially in the presence of changes in the cardiovascular and respiratory systems, the inspiratory volume was not significantly changed, but a sharp decrease took place in the supplemental air. Irregularities of the rhythm of respiration quickly developed.

The reduction in the VC and supplemental air in these conditions suggests that these changes are associated with an increase in the residual volume of the lungs and in the volume of the functional residual air. The volume of the dead space, as defined by Gray and Carter, was not substantially changed in hypoxic conditions. The so-called vital index showed changes similar to those in the VC.

So far as the pulmonary ventilation is concerned, the minute volume (MV) rose regularly during hypoxia in most subjects, mainly on account of a deepening of respiration. However, in patients with disturbances of cardiovascular function, the increase in the MV was not statistically significant (probability only 90%), thus indicating a degree of inadequacy of the adaptive reactions of the organism in these cases.

Whereas in the healthy subjects, with their higher resistance to hypoxia, a significant deepening of respiration

Changes in Respiration in Subject E during Hypoxia

Index	Initial values when breathing		At an "altitude" of 5000 m and breathing	
	air	oxygen	air	oxygen
Respiration rate per min	10	10.9	11.4	11.7
Tidal air (in ml)	540	460	500	680
MV (in liters)	5.4	5.04	5.72	8.0

and a slight increase in its rate (on the average by 2.5 breaths/min), in subjects with impaired function a slowing of the respiration rate was often observed, with an inspiratory pause. This confirmed to some extent M. E. Marshak's opinion [5] that permanent excitation of the inspiratory portion of the respiratory center is present when the CO₂ pressure in the arterial blood falls, as is the case, for example, in hypoxia.

Investigations conducted on subjects breathing oxygen are of particular interest in the elucidation of the physiological mechanisms of the changes described above.

At an altitude of 5000 m the change to breathing oxygen usually led to a decrease in the MV, mainly on account of a decrease in the tidal air. In persons with cardiovascular diseases the pulmonary ventilation, which changed relatively little in hypoxic conditions, rose clearly during inhalation of oxygen as a result of a deepening and a slight increase in the rate of respiration. This is illustrated by the following example.

Subject E., aged 40 years; diagnosis: initial manifestations of cardiosclerosis. Resistance to hypoxia satisfactory. The results of the investigation are given in the table.

Hence, an adequate adaptive reaction of the organism to hypoxia is an increase in the ventilation of the lungs as a result of a deepening of respiration. A decrease or no change in the pulmonary ventilation in these conditions indicates impairment of the adaptive reactions. These phenomena are not encountered in healthy persons, but arise frequently in persons with disturbances of cardiovascular function.

SUMMARY

A study was made of 203 persons in a pressure chamber under conditions equivalent to "ascents" to 5000 m, with inhalation of an 11% O₂ nitrogen mixture. Only moderate changes in the respiration rate, vital capacity of the lungs, and in the complementary and supplementary air were noted in cases with good hypoxia tolerance. The tidal air inspiratory volume and pulmonary ventilation were increased. No significant changes in the pulmonary ventilation were observed in persons with pathologic conditions of the cardiovascular system, pointing to an inadequacy of the adaptive reaction of the body. When the state of the subjects became worse, there was a decrease in the respiration rate frequency attended by an inspiratory pause, a marked drop in the supplementary air, and a reduction in pulmonary ventilation.

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