

## HYPOXIC PHENOMENA IN MUSCLE ACTIVITY

M. E. Marshak and T. A. Maeva

Laboratory of the Physiology and Pathology of Respiration and Circulation (Director: Prof. M. E. Marshak) of the Institute of Normal and Pathological Physiology (Director: Prof. V. N. Chernigovsky, Acting Member of the Academy of Medical Sciences USSR), Moscow

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It has been established, in study of the dynamics of the change in the degree of oxygen saturation of arterial blood in man with the aid of an oximeter, that muscular work is often accompanied by a deterioration in the arterialization of the blood, not only in sick persons but also in healthy individuals [1].

It has also been determined that hypoxic phenomena during muscular activity occur in untrained individuals still lacking adequate coordination for the given work [1]. In these cases a reduction in the oxygen saturation of arterial blood usually begins even in the first few minutes of work, during the period while the movements are being planned, when the lack of coordination in the activity of the various systems of the body is quite pronounced.

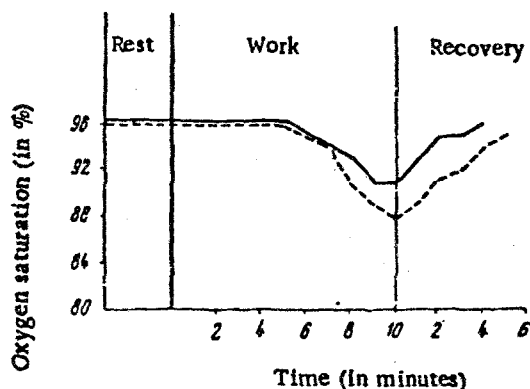


Fig. 1. Change in the degree of oxygen saturation of the blood during work on the ergometer bicycle for 10 minutes in subjects P. (—) and S. (----).

Investigations conducted earlier showed that in cases where deterioration in the arterialization of the blood occurs as a result of a disruption of the correlation between the aeration and the blood supply of the various parts of the lungs, the inspiration of oxygen ensures full oxygen saturation of the arterial blood.

However, in subsequent investigations, the results of which are set forth in this paper, we noted that sometimes a drop in the oxygen saturation of the arterial blood sets in, not at the very start of the work, but 5-6 minutes later, and that it lasts until the end of the 10- to 12-minute work (Fig. 1).

During the second half of the work, in order to prevent the development of hypoxia, we supplied oxygen to the subjects during the work in a number of cases.

As will be seen from Fig. 2, when oxygen is breathed the oxygen saturation of the arterial blood remains at the 100% level for the first 5 minutes, and then, although the subject continues to breathe oxygen, the arterialization of the blood begins to deteriorate.

In the case shown in Fig. 2 oxygen inspiration considerably reduced the drop in the oxygen saturation of the arterial blood observed with the breathing of air, although the percentage of saturation showed some decline during the second half of the work. Thus, despite oxygen breathing, during the latter minutes of work there was still a "deficit" in the oxygen saturation of the arterial blood (in Fig. 2 this deficit is shown by the hatched area).

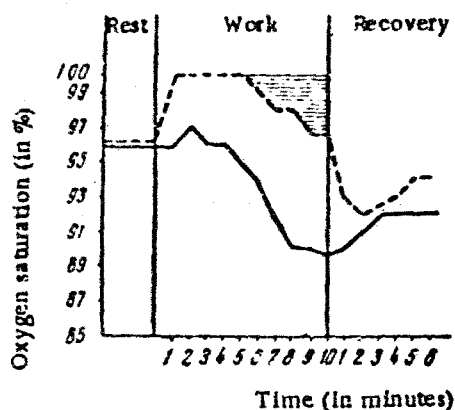


Fig. 2. Degree of oxygen saturation of the arterial blood during work on the ergometer bicycle: with breathing of atmospheric air (—) and with breathing of oxygen (---).

degree of oxygen saturation of the arterial blood not change, and then, when the coordination of functions for the given work should have been established and to some extent improved, why should the arterialization of the blood deteriorate?

It is known that some minutes after the beginning of muscular work of medium intensity the need for oxygen, the lung ventilation, the minute volume of blood, etc., become fixed at a set level, at which they remain until the end of the work, regardless of its duration. A "stable condition" sets in [3]. However, we found that as the duration of work of medium intensity is increased some functions do not change, while others undergo considerable changes [2]. The principal significance of this observation lies in the fact that it shows the conditional nature of the concept "stable condition". The fact that in our experiments the percent of oxygen saturation of the arterial blood began to fall after a few minutes of work indicates that certain shifts began in the body, which led to a reduction in the effectiveness of the external breathing.

The drop in the oxygen saturation of the arterial blood must be considered a result of disruption of the normal relationships between breathing and the blood circulation in the lesser circulatory system. It is natural to assume that certain shifts must have commenced in breathing and the circulation which during the second half of the work led to a disruption of the normal interconnections of these systems.

There are some data in our material to support this hypothesis. Using a photoelectric pickup we recorded the subject's pulse during the whole period of the work. It was shown that in the investigations in question the pulse frequency increased until the end of 10- or 12-minute work (Fig. 3); in some cases the heartbeat frequency increased more after the first 6 minutes than during them.

During the 10-minute work we took several readings of the blood pressure. It was shown that during the 6th-8th minute of work there is a 10-15 mm increase in the maximal pressure after a preceding stabilization of the pressure at an elevated level in the 3rd-6th minute.

In a number of the investigations a slight increase was noted in lung ventilation as the duration of the work was increased; sometimes lung ventilation gradually increased from the beginning of the work, reached a steady level in the 4th-6th minute, and then increased somewhat.

The above data show that under the conditions which we set for our investigations there actually were shifts in the respiratory and circulatory systems, increasing with the duration of the work; a "stable condition" did not set in, although, by A. Hill's classification [3] the work performed was of medium intensity; the subjects were in a condition to go on with it. It is important to note that the functional changes, mentioned earlier, taking place as the duration of the work was extended, set in only with work of comparatively heavy intensity (in our cases the oxygen requirement during the work reached 2000 ml/min). When the intensity of the work

In other experiments, with oxygen breathing the oxygen saturation of the arterial blood was 89-100% in the third and fourth minutes of work, while with oxygen inspiration the level of oxygen saturation was only 94% in the 7th-8th minute of work.

These data indicate that the reduction in the degree of oxygen saturation of arterial blood which set in after a few minutes of work was caused not only by insufficient oxygenation of one portion of the blood as a result of lack of equilibrium between the ventilation and blood-supply of the various groups of alveoli, but also by the fact that some portion of the blood passed from arteries into veins, bypassing the alveolar capillaries; this may have been due to the development of artery-vein anastomoses.

We were faced with the problem of explaining the phenomena we had observed. Why, during the first 5-6 minutes of work, the warm-up period when the body is becoming adapted to the work, does the

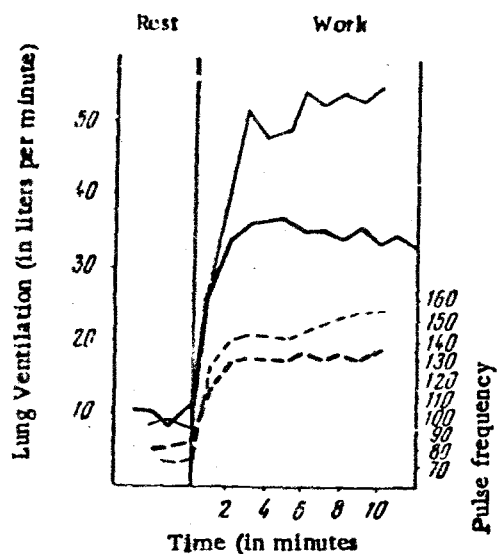


Fig. 3. Lung ventilation (—) and pulse frequency (---) during light work (heavy lines) and heavy work (thin lines) of medium intensity, lasting ten minutes.

#### LITERATURE CITED

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- [2] M. E. Marshak, *Fiziol. Zhur. SSSR*, Vol. 17, No. 4, pp. 853-861 (1934).
- [3] A. V. Hill, *Work of the Muscles\** (Moscow-Leningrad, 1929).

\*Translated into Russian.

on the ergometer bicycle was decreased for the same subjects the oxygen saturation of the blood did not change during 10-12 minutes of work, while the activity of the cardiovascular and respiratory systems reached a steady level in the 3rd-4th minute of work, remaining practically unchanged until the end of work (Fig. 3).

Thus, in speaking of work of medium intensity, one should distinguish according to the body reactions work which is at the borderline of work of so-called "submaximal intensity" which a person can perform for only 2 to 5 minutes while meeting all his oxygen needs during the period of work.

At some level of intensity (different in different individuals) soon after commencement of the work, functional shifts set in, indicating a disruption in the coordination of functions adequate for the performance of the work; one of the results of this is the appearance of hypoxic phenomena.