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ABSTRACT

The work is devoted to the study of the effect of complete hyper- and hypoventilation breathing on the parameters of the blood flow microcirculation. Volunteers achieved hypo- and hyperventilation modes by performing full breathing. The correlations found between parameters of gas analysis and blood microcirculation may indicate the peculiarities of the mechanisms of oxygen delivery to biological tissues during the changes in breathing mode.

Keywords: microcirculation, breathing, yoga, spirometry, laser Doppler flowmetry, wearable analyzers

1. INTRODUCTION

Full yoga breathing represents an arbitrary change in the minute ventilation both upward (hyperventilation) and downward (hypoventilation) with corresponding changes in gas exchange. Some yoga breathing exercises are included in the complexes of rehabilitation after respiratory diseases.[1] However, currently there is a limited number of works devoted to the study of the influence of such breathing modes on the functional state of the microvascular bed of the circulatory system.[2,3]

The purpose of this work was to study the relationship between the respiratory system and the microcirculatory bed during hyper- and hypoventilation yoga breathing.

Laser Doppler flowmetry (LDF) is one of optical noninvasive registration of the parameters of the functional state of the microvascular bed.[4] The LDF method is based on the probing of tissues by laser radiation in the near-infrared range and the analysis of light reflected from erythrocytes. LDF makes it possible to evaluate the work of peripheral blood flow regulation mechanisms.[5] The active mechanisms include endothelial (Ae; 0.0095-0.021 Hz), neurogenic (An; 0.021-0.052 Hz) and myogenic vasomotor (Am; 0.052-0.145 Hz), associated with muscle tone of precapillary sphincters. The passive mechanisms are respiratory (Ar; 0.145-0.6 Hz) and cardiac (Ac; 0.6–2 Hz).

2. MATERIALS AND METHODS

The study sample included 22 people (16 men, 6 women) who regularly practice full yoga breathing. All volunteers considered themselves subjectively healthy and did not take any pharmacological drugs on a regular basis.

Skin perfusion of blood was registered for all participants by using portable laser blood microcirculation analyzers "LAZMA PF" (LAZMA Ltd, Russia; in EU/UK this device made by Aston Medical Technology Ltd., UK as "FED-1b"), integrated into a distributed system of these monitors.

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The devices were fixed symmetrically to the right and left side in the areas of the basins of the supraorbital arteries, the volar surface of the distal phalanges of the third fingers and first toes in such a way as not to create pressure on the study area.

Volunteers were in a sitting position; hands were placed on the table at the heart level. Studies of blood microcirculation parameters were performed according to the protocol presented in Table 1.

Table 1. Protocol of experiments

Research stage	Stage Description	Duration, min
1	Registration of LDF against the background of free natural breathing	6
2	Special mode of full breathing according to one of the schemes: 1. Hypoventilation: 30:30 (30 s – inhale; 30 s – exhale) or 20:20 2. Hyperventilation: 10:10 (10 s – inhale; 10 s – exhale) or 8:8	5
3	Registration of LDF against the background of free natural breathing	6
Total time		17

Representative graphs of the index of microcirculation and its wavelet spectrum are shown in Fig. 1. During the full yoga breathing the excursion of the chest is increased, and because of it, the respiratory process dominates the mechanisms of microcirculation regulation. It forms sinusoidal oscillations on the graph of the index of microcirculation (Fig. 1a) and manifests itself as the dominant frequency on the wavelet spectrum (Fig. 1b).

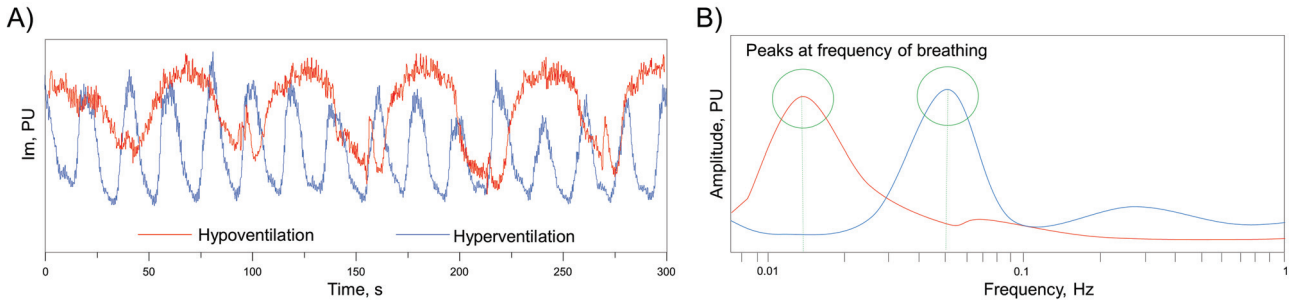

Figure 1. Examples of index of microcirculation (A) and its wavelet spectrum (B) in hypo- and hyperventilation mode

Spirometry and gas analysis were performed in the sitting position. To stop nasal breathing, a clamp was used, and breathing was performed through the mouth into the tube of the device using an antiviral filter "Vitalograph".Using a MAC-2C spirometer with the function of gas analysis and pulse oximetry (manufactured by "Belintelmed", Belarus), the following parameters were determined for each volunteer: percentage of O_2 in exhaled air (FeO_2) and tissue saturation (SpO_2).

3. RESULTS AND DISCUSSION

Data from spirometry and gas analysis of volunteers obtained during the full breathing and 3rd stage data of blood microcirculation parameters were used (Tab. 1). It is not possible to use the stage 2 results of LDF recordings (Tab. 1) due to the loss of information about the work of microcirculation regulation mechanisms (the respiratory mechanism dominances (Fig. 1)).

A positive correlation between the tissue saturation of the hypoventilation regime and the amplitudes of cardiac oscillations of the recovery period after hypoventilation (Fig. 2a) means unidirectional changes in these parameters. It can be assumed that in response to a decrease in tissue saturation during hypoventilation, compensatory reactions are triggered in the most vulnerable organs, together with the absence of an increase in arterial inflow in the skin of the forehead, this may indicate a redistribution of arterial blood into the blood vessels of the brain.

In the third fingers, there is a negative correlation of nutritive blood flow with the percentage of oxygen in the exhaled air (Fig. 2b). This correlation may indicate the inclusion of a compensatory mechanism in the form

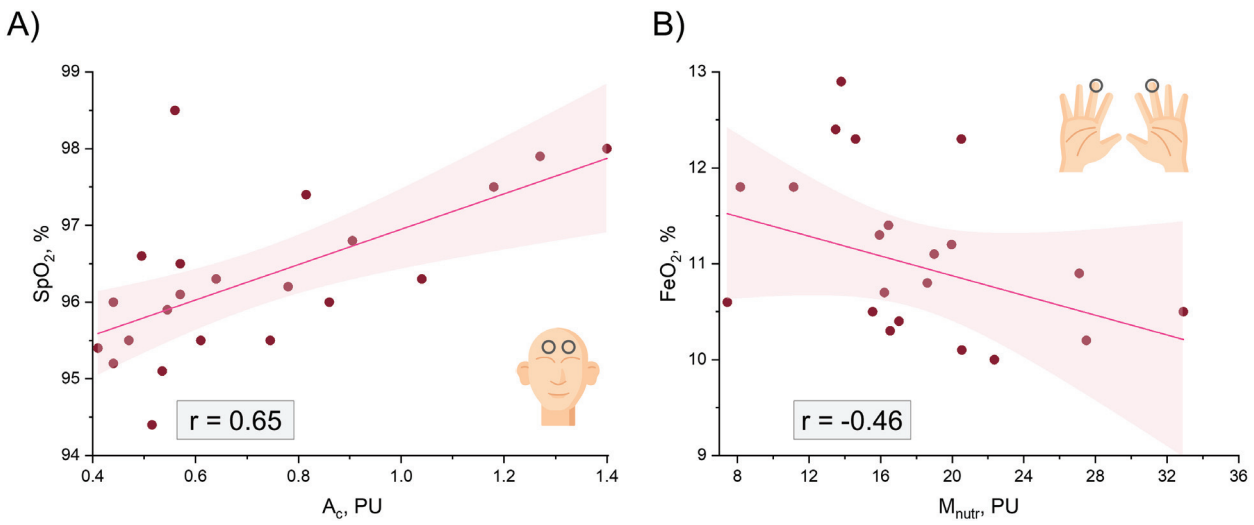

Figure 2. Correlation plot for parameters of spirometry and laser Doppler flowmetry recording for hypoventilation: tissue saturation and amplitude of cardiac oscillation in area of supraorbital arteries (A); percentage of O2 in exhaled air and nutritive blood flow in area of third fingers (B). Red line - Spearman's linear fit; red area – 95 % confidence band; r - Spearman correlation coefficients, $p<0.05$

of redistribution of total perfusion into the capillary bed, as a response to a lack of oxygen in the blood because of a hypoventilation mode of breathing.

4. CONCLUSIONS

The study showed that there is a correlation between the parameters of blood microcirculation and gas analysis during hypo- and hyperventilation breathing, which may reflect the inclusion of compensatory mechanisms on the part of the microcirculation in response to various breathing modes.

The results obtained can be useful in studying the peculiarities of the mechanisms of oxygen delivery to biological tissues in different breathing modes, and will also allow us to develop an instrumental method for monitoring the performance of full breathing exercises and their effectiveness in rehabilitation.

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