Respiratory system response to immersion in water under standard swimming pool conditions

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Abstract

Objective of the study was to evaluate the response of the external respiratory system of healthy men to immersion of the whole body in water under standard conditions of a swimming pool.

Methods and structure of the study. The experiment involved 10 apparently healthy volunteers of the first mature age (all men). A continuous ergospirometric study was carried out under full immersion in water under standard swimming pool conditions.

Results and conclusions. It is shown that being in comfortable conditions of the aquatic environment leads to an increase in the rate of energy consumption. An urgent reaction to full immersion from the cardiovascular and respiratory systems is described. In particular, an increase in oxygen consumption and carbon dioxide release, an increase in the respiratory exchange coefficient and the formation of deep breathing at a constant frequency were recorded.

Keywords: *ergospirography, healthy volunteers, comfortable temperature, breathing depth, metabolism.*

Introduction. The use of the aquatic environment to improve human health is very widespread from hardening in natural conditions to training sessions in swimming pools. Water has a number of distinctive features that determine, in particular, its effect on the body. For example, the specific thermal conductivity of water is 17 times higher than the specific thermal conductivity of air [2]. Thus, the cooling of the body in the aquatic environment proceeds more intensively [1]. So, in water with a temperature of 25–26°C, a naked person loses twice as much heat in one minute as in an air environment with the same temperature [2]. As a result, the thermal sensations of the body in air and in water at the same temperature are different. If 23°**C** of air is felt as "indifferent" temperature, then in water it is "cool" [1].

When the body is cooled, the external respiration system is actively involved in response, since, along with a specific respiratory function, this system is involved in thermoregulation [5]. Numerous studies of local hypothermia on the human body describe the reaction of the respiratory system according to spirography data [3]. It has been shown that the cooling of the extremities at 24°C of water already causes a slight strain on the body [6]. And short-term immersion of the whole body in water at 20°C enhances the interaction between large brain networks [8]. At the same time, studies of the reaction of the external respiratory system with complete immersion of the whole body in water cover only extreme temperatures - up to 15°C [5].

Objective of the study was to evaluate the response of the external respiratory system of healthy men to immersion of the whole body in water under standard conditions of a swimming pool.

Methods and structure of the study. The experiment involved 10 apparently healthy volunteers of the first mature age (all men). In addition to the age and gender criteria, the following conditions for inclusion in the observation group were indicated - height 170-175 cm, body mass index 20-24 kg/m2, average level

of physical activity (3000-4000 MET-min./week). The exclusion criteria were chronic respiratory diseases, a history of an acute illness within the last three months, smoking, regular water drinking (including winter swimming). The study design is shown in fig. 1. A continuous ergospirometric study was carried out under full immersion in water under standard swimming pool conditions (Fig. 2). The following indicators were recorded in the study - heart rate (HR), oxygen and carbon dioxide consumption (VO2 and VCO2, respectively), respiratory exchange ratio (RER), tidal volume (VT), respiratory rate (BF) and metabolic equivalent of work (MET). To monitor the above indicators, a portable gas analyzer PNO (https://pnoe.com/) [9] was used.

Results of the study and their discussion. The requirements for the water temperature in the pool bath and for microclimate conditions are strictly regulated by the relevant standard [8]. In particular, the water temperature for educational and recreational pools ranges from 26°C to 29°C, the air temperature is 1-2°C higher than the water temperature, and the relative air humidity is not more than 65% [4]. The temperature parameters and relative humidity during the study are shown in Figure 2.

Despite the fact that the water temperature of 23-26 °C is considered comfortable for water procedures and you can stay in it for quite a long time, there is an urgent adaptive effect on the cardiorespiratory system. The results of ergospirometry are presented in the table (data grouped by 30-second time intervals). The change in heart rate when completely immersed in water begins to increase after one and a half minutes of being in water, while the maximum value is recorded in the first 30 seconds after leaving the water, and the return to the value at rest occurs in the second minute.

Unlike heart rate, changes in the respiratory system occur already in the first 30 seconds after immersion in water. So, oxygen consumption increases three times with full immersion immediately and within two minutes there is a gradual decrease in it. At the same time, after leaving the water, a minute later, a value is also recorded that is 2.5 times higher than the rest level and its subsequent decrease. A similar increase and decrease in carbon dioxide emissions is observed when performing full immersion in water, although the rate of change of VCO2 is greater than that of VO2. This is confirmed by the change in the value of the coefficient of respiratory exchange.

It should be noted that throughout the entire ergospirometric recording, the respiratory rate remains approximately the same, while the tidal volume varies significantly. Thus, during the first minute after a complete immersion, the tidal volume more than doubles and generally remains elevated throughout the entire time of immersion. After leaving the water, by the end of the first minute, a twofold increase in tidal volume is also noted.

Full immersion in water at a temperature of 26°C affects the rate of energy consumption, which is reflected in the value of MET. During the first 30 seconds after a dive, MET triples and gradually decreases, remaining above the level at relative rest until the dive. After leaving the water, this parameter also remains elevated and by the end of the first minute it increases by 2.5 times compared to the rest level before the dive.

Conclusions. Thus, even being in comfortable conditions of the aquatic environment leads to an increase in the rate of energy consumption. Immediately upon complete immersion in water, an urgent reaction

Sample values according to the study

Environment	Time, min.	Heart rate, bpm	VO_2, ml/min	VCO_2, ml/min	RER, conv. units	VT, l	BF, b.m/min.	MET, conv. units
Air	до	68±2	339±5	294±4	0,87±0,01	0,57±0,02	21±2	1,37±0,03
Immersion in water								
Water	0,5	67±3	1023±12	890±9	0,87±0,01	1,28±0,04	24±3	4,12±0,04
	1	68±2	832±4	766±5	0,93±0,02	1,26±0,04	22±2	3,35±0,04
	1,5	74±4	590±8	540±8	0,93±0,02	0,98±0,02	20±3	2,38±0,03
	2	82±3	496±7	502±5	0,97±0,02	1,01±0,03	20±3	2,00±0,02
Getting out of the water								
Air	0,5	93±4	374±4	317±8	0,89±0,01	0,63±0,03	22±2	1,51±0,02
	1	83±4	864±6	763±9	0,85±0,01	1,14±0,04	25±1	3,48±0,04
	1,5	75±3	749±6	592±5	0,79±0,01	0,97±0,02	22±3	3,02±0,04
	2	67±23	487±5	435±6	0,89±0,01	0,73±0,02	22±2	1,96±0,03

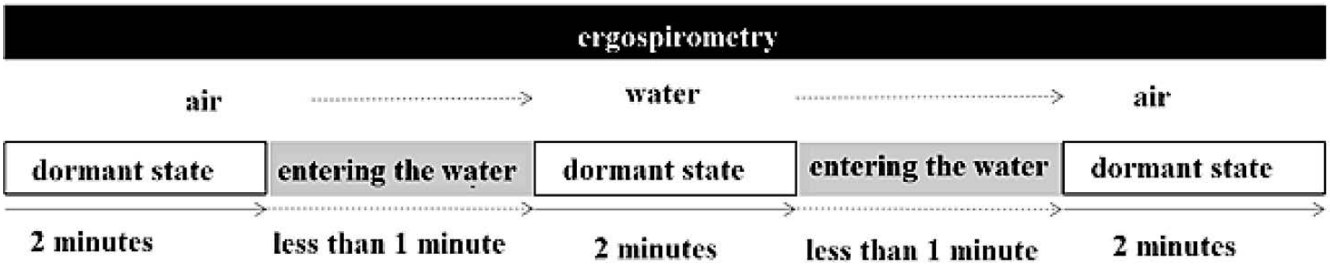

Figure 1. *Study Design*

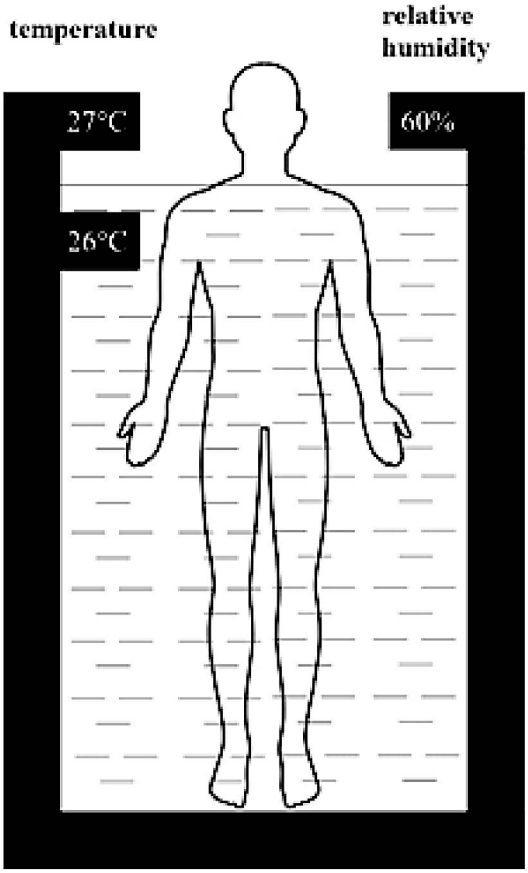

Figure 2. *The position of a person when completely immersed in water*

from the respiratory system is noted, which consists in an increase in oxygen consumption and carbon dioxide release, the value of the respiratory exchange coefficient increases, and the depth of breathing increases at a constant frequency. After leaving the water, similar changes in the recorded parameters occur after a minute, and the degree of severity of these changes is slightly less. Unlike the respiratory system, the heart reacts with an increase in heart rate not immediately, but a minute after complete immersion. Along with this, the pulse becomes high after leaving the water. Excitation of temperature receptors (heat and cold) leads to excitation of the respiratory center, which creates conditions for increased activity of the respiratory system. In this case, probably more respiratory muscles are involved in the work, which provides deeper breathing at a constant frequency. Gradual activation of cold receptors, in turn, leads to stimulation of the sympathetic division of the autonomic nervous system [7], which affects cardiac activity.

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