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ARTICLE *in* BULLETIN OF EXPERIMENTAL BIOLOGY AND MEDICINE · JULY 2010

Impact Factor: 0.36 · DOI: 10.1007/s10517-010-1075-0 · Source: PubMed

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Relationship between Lactate Concentrations in Active Muscle Sweat and Whole Blood

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Translated from *Byulleten' Eksperimental'noi Biologii i Meditsiny*, Vol. 150, No. 7, pp. 94-96, July, 2010
Original article submitted November 18, 2009

Lactate (lactic acid) concentrations in sweat and venous and capillary blood of athletes were measured before and after exercise of the maximum aerobic power. Correlations between the increment of blood and sweat lactate concentrations were found. Lactate concentrations in the sweat can be used for evaluation of changes in blood lactate levels.

Key Words: *lactic acid; lactate; sweat; exercise*

The search for noninvasive methods for analysis of physiologically significant substances attracts great attention in recent years. Along with high availability, these methods should be sufficiently sensitive and selective [2].

Lactate (the final product of tissue glucose metabolism) is present in the blood, saliva, urine, and skin excretion and is one of the substances most important for analysis. The data on blood lactate concentration are essential for monitoring oxygen deficit in clinical medicine and sports physiology [1,3].

Measurement of venous blood lactate is an important diagnostic test for evaluation of shock and hypoxia. Lactate level and the time course of its changes are prognostic criteria for predicting the development of lesions in sepsis, trauma, shock, and burns. In sports physiology, lactate level reflects exercise intolerance in the athletes [8,12].

Two approaches to measurements of blood lactate concentrations are used at present in clinical and sports practice: electrochemical and spectrophotometric. However, analysis of venous and capillary blood, obligatory in both cases, is difficult and has to be performed by highly qualified medical staff with consideration for rigid hygienic regulations [1-3].

The procedure can be simplified by using easily available biological fluids, *e.g.*, sweat. Together with water, the sudoriferous glands release many metabolites: urea, some salts, uric acid, and lactate.

We studied the relationship between blood lactate concentration and its concentration in the active muscle sweat and developed a method for the analysis of blood lactate concentration based on its sweat concentration.

MATERIALS AND METHODS

The test with step-wise increasing power [10,11] served as the model exercise. Experiments were approved by the Ethic Committee of the Institute Physical Culture. The study was carried out in 14 trained athletes engaged in cyclic sports (age 23.6±3.2 years, weight 71.8±3.5 kg, height 177.4±5.8 cm, maximum oxygen consumption (MOC) 65.5±7.8 ml/min/kg). Venous and capillary blood was collected simultaneously before and directly after model exercise. Lactate concentra-

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tion in capillary blood was measured by electrochemical method on a C_Line automated analyzer (Biosen). Lactate level in venous blood was measured by spectrophotometry using LC 2389 kit (Randox).

In order to collect a sweat specimen at rest, a skin site above the gastrocnemius was stimulated with 1% pilocarpine chloride (Ferein) electrophoresis (Potok-1 device). After stimulation of the skin site, the sweat was collected with a Macroduct Sweat Collector for 15 min. The sweat was collected from the same skin site after model exercise.

Lactate level in the sweat was measured using screen-printed planar electrodes. The electrochemical system included a working graphite electrode (2 mm in diameter), accessory graphite electrode, and the reference silver chloride electrode [6,7]. The measurements were carried out in a flow engineering system at constant flow velocity 0.4 ml/min in phosphate buffer (pH 7) on a PalmSens device in the amperometric mode [6,7].

Experimental data were processed by descriptive statistical methods and presented as the arithmetic mean and standard error ($M \pm m$). The significance of differences between unrelated samples was evaluated by Mann–Whitney's test. Statistical hypotheses were verified at the critical level of significance $p=0.05$.

RESULTS

Lactate concentrations in the sweat, capillary and venous blood were measured (Table 1). The values before and after exercise test differed significantly ($p<0.05$).

Statistical analysis of the data found no correlations between the absolute values of lactate concentrations in the sweat and capillary and venous blood ($R^2=0.12$, $p>0.05$; $R^2=0.46$, $p>0.05$, respectively).

TABLE 1. Lactate Concentration in Biological Fluids ($M \pm m$)

Specimen	Lactate concentration, mmol/liter	
	before exercise	after exercise
Venous blood	3.0±0.5	7.2±0.7
Sweat	20.4±6.7	62.2±16.3
Capillary blood	1.6±0.5	9.7±1.2

Since lactate concentration in the sweat includes not only blood lactate, but also lactate production by the eccrine sudoriferous gland, it is justified to evaluate the contribution of the working muscle by the increment of lactate concentration as a result of intense exercise: ($C_{lactate}$ after exercise – $C_{lactate}$ before exercise)/$C_{lactate}$ before exercise.

Analysis of experimental data with consideration for this hypothesis showed that the increase in lactate concentration in the sweat correlates with the increment of its concentration in capillary blood ($R^2=0.72$, $p<0.05$; Fig. 1, *a*). The increment of lactate concentrations in venous blood correlates with that in capillary blood ($R^2=0.84$, $p<0.05$; Fig. 1, *b*).

Hence, a relationship between lactate concentrations in the blood and the working muscle sweat was found. It was previously shown that lactate concentrations are elevated in the perspiration of skin areas above the working muscle, but no statistically signifi-

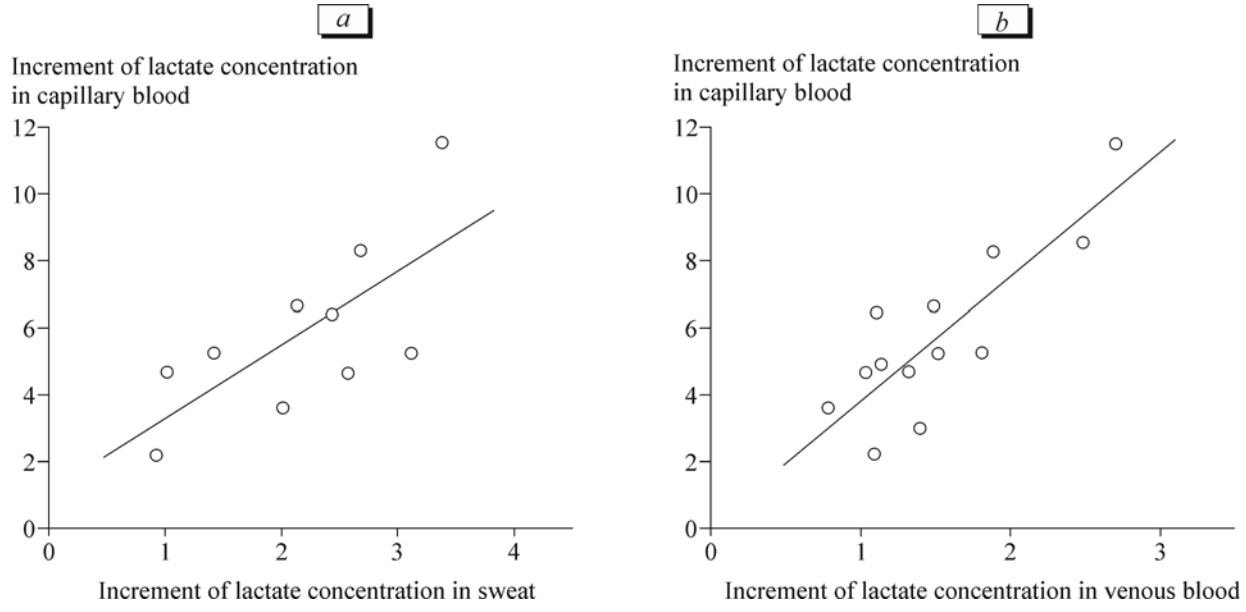

Fig. 1. Correlations between increment of lactate concentrations after exercise test. *a*) capillary blood – sweat; *b*) capillary blood – venous blood.

cant correlations were found in lactate concentrations in the sweat in different skin sites and total lactate concentration in whole-body sweat [9]. It was shown [4,5] that total lactate concentration in whole-body sweat does not reflect the intensity of exercise. On the other hand, it is noteworthy that exercise described in a previous study [4] (30 min 45% MOC and 15 min 80% MOC) are within the threshold lactate zone and therefore cause no appreciable increment of blood lactate concentration. We used a highly intense exercise beyond the threshold lactate level in this study. This exercise is associated with lactate accumulation in capillary and venous blood and in the sweat (Table 1).

The study showed the possibility of using sweat from skin sites above the working muscles for noninvasive evaluation of blood lactate levels. In addition, the use of a new planar biosensor for lactate has demonstrated its high efficiency in studies of sweat lactate levels.

The study was supported by the Federal Agency for Science and Innovations within the framework of Federal Target Program "Research and Development of Priority Trends for Scientific and Technological Complex of Russia for 2007-2012" (grant No. 02.512.12.2028).

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