

A SIMPLIFIED METHOD FOR THE DETERMINATION OF BLOOD LACTIC ACID LEVELS IN OCCUPATIONAL HEALTH PRACTICE

A. K. GANGULI, R. HEMALATHA AND B. NARAYANAN

*National Model Centre for Occupational Health Services,
Bharat Heavy Electricals Ltd., Tiruchirapalli - 620 014*

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Summary : Blood lactate assays are now widely used as measures of oxygen debt, especially in the areas of (a) assessment of anaerobic power; (b) assessment of fatigue; (c) $\dot{V}O_2(\max)$ end-point determination, and (d) rationalisation of work-rest cycles. A need exists for a method which will meet the following criteria : (a) simplicity - single, small samples; (b) rapidity, and (c) feasibility with easily available instrument and chemicals. In order to develop such a method, the standard Barker and Summerson (4) method was modified so as to use 0.02 ml of blood sample, and the following tests were carried out on 25 subjects at rest, and various levels of work : (a) Paired comparisons on analysis by macro and micro methods on the same sample of blood; (b) Paired comparisons on venous and capillary (fingertip) samples. In both cases, the paired values showed high correlation (0.99) and highly significant differences of means ($P = 0.01$ and 0.001 , respectively). The regression equations obtained were also highly significant ($P = 0.001$). The combined equation was $Y = 0.9655 x - 0.4366$; (c) Samples taken 2,4,5,6 and 10 mins after work showed that peak occurred in the 4th min sampling (2 vs 4 and 4 vs 6 min means significantly different at $P = 0.05$, and analysis of variance significant at ($P = 0.001$). It may be concluded that drawing fingertip sample 4 mins after the end of work, analysing by the micro method, and using the regression equation will give the true peak blood lactate level, and satisfy the systems criteria defined.

Key words :

lactic acid
occupational health

exercise biochemistry
industrial physiology

INTRODUCTION

Blood lactate assays are now widely used as measures of oxygen debt in all work physiology laboratories. In this context, the term work physiology is used to cover such relevant disciplines as sports physiology occupational physiology and industrial physiology.

Knowledge of the blood lactate level is of importance in four areas :—

- (1) Assessment of anaerobic power,
- (2) Measurement of maximal aerobic capacity,
- (3) Rationalization of work-rest cycle,
- (4) Assessment of fatigue.

Lactic acid is produced in the muscles during actual work, but there is a time-lag for the diffusion from the working muscles and redistribution within the body. For a determination of peak lactic acid values in blood, samples must be taken during the 5th to 10th minute of the recovery period (2). Sen Gupta *et al.* (3) reported drawing of capillary samples 5 min after end of exercise.

A repetitive invasive procedure, especially on the shopfloor or other work-site, is an anathema to occupational physiology. Reasons include hygienic aspects, time off from production, psychological effects on productivity and attracting a large group of spectators. Furthermore, enterprise level occupational health services are seldom likely to have access to spectrophotometers or able to stock reagents for enzyme based assays. Thus a need exists for the definition of a rapid and simple test which can be carried out without sophisticated instruments, and which provides reliability within the limits required by occupational health practice. The criteria for such a test would be (1) simplicity - feasibility of drawing a small sample, a procedure attracting a minimum amount of attention; (2) rapidity - a procedure involving minimum expenditure of time off from work; and (3) ability to be carried out using easily available instruments and chemicals, at an Occupational Health Centre rather than only in research institutions or pathological laboratories.

The use of capillary blood samples and colorimetric methods satisfy most of the above criteria, but the variability of the results is high, with consequent low system reliability. The variability may be attributed to two sources :— methodological (differences in lactic acid concentration between venous and capillary blood, etc.) and chronological (time of sampling may or may not coincide with the lactic acid peak). Removal, control or compensation for these sources of variability would raise the system-reliability to an acceptable level. The objectives of this study were to prescribe (a) a time for sampling, and (2) a factor to compensate for methodological variations, so as to arrive at an acceptable measure of the peak lactic acid level in venous blood based on a single small sample of capillary blood.

MATERIAL AND METHODS

The basic study consisted of three phases. In the first phase, blood samples were drawn from the antecubital vein of twenty-five subjects. All the subjects were university level atheletes. Subjects were randomly chosen, in various levels of rest and work.

These samples were analysed both by the standard Barker and Summerson method (4) (referred to hereafter as the 'macro' method), and also by a modification in the method to use only 0.02 ml of blood (referred to hereafter as the 'micro' method) standardised during earlier work in this laboratory (5). The modifications consist of only proportional reductions in the amounts of other reagents so as to maintain concentrations identical to the macro method throughout, and use of micro sample tubes for the Klett Colorimeter.

In the second phase, paired samples were drawn simultaneously from the ante-cubital vein and the tip of the second or third finger. Samples were drawn after arterialisisation (pre-warming by dipping in warm water and careful drying). Twenty-five subjects were chosen randomly, in various levels of rest and work.

In the third phase, twentyfive subjects were asked to perform graded dynamic exercise on an electrical bicycle ergometer. The exercise protocol consisted of 5 mins work at 2.0, 2.5 and 3.0 Watts per kg weight. The first two spells were followed by one minute rest, but after the third spell, the load was increased at the rate of 15 W/min till exhaustion. Blood samples were drawn from the finger-tips before exercise and 2,4,6,8 and 10 min of recovery period and analysed by the micro method.

During all exercise tests, heart rate was continuously monitored by a digital rate-meter, which sampled R-R intervals from the ECG; and oxygen consumption was monitored by Morgan OXYLOG, a ventilometer-gas analyser-computer giving digital minute-to-minute displays of \dot{V}_{O_2} in l/min STPD.

Partly because of the results obtained in the third phase and partly because the third phase represented exhaustive work a fourth set of data was collected. Fifteen subjects were asked to perform graded dynamic work as above, but did not continue after the end of the third spell (i.e. did not continue to exhaustion). Samples were drawn from the fingertips after 4,5 and 6 min of recovery and analysed as above.

RESULTS

Table 1 shows the result of the first phase study. The paired T-test between the data obtained by the macro and micro methods showed a significant difference ($p = 0.01$) and a very high correlation ($r = 0.99$).

TABLE 1 : Venous blood lactate (mg%) macro vs micro method.
(n=25)

Method	AM	SD	SE
Macro	39.0	26.18	5.24
Micro	37.0	24.20	4.84

$r = 0.99$., Paired-T = 2.89; Significant at $p = 0.01$

Table II shows the differences between the lactate levels obtained from venous and capillary blood. Paired T-test showed a very highly significant difference ($p = 0.001$) and the correlation between the data sets was very high ($r = 0.99$).

TABLE II: Blood lactate ($mg\%$) by micro method venous vs capillary blood.
($n=25$)

Source	AM	SD	SE
Venous	23.7	20.90	4.179
Capillary	26.1	23.04	4.607

$r = 0.99$; Paired-T = 4.03; Significant at $p = 0.001$.

Phase three results are tabulated in Table III-A which shows the time pattern of the lactic acid levels, as measured by the micro method. The variance ratio at d.f. = 4,120 was very highly significant ($p = 0.001$).

TABLE III-A: Blood lactate ($mg\%$) at different intervals (micro method).
($n = 25$)

Time	AM	SD
Pre-work	18.2	2.62
2 mins recovery	64.1	10.74
4 mins recovery	72.4	10.53
6 mins recovery	65.5	11.61
8 mins recovery	62.6	10.65
10 mins recovery	58.0	12.15

$F = 5.31$; $p (4/120) = 0.001$.

TABLE III-B: Comparison of mean lactate levels (micro method) at different times by T-test.

Time (Recovery) (min)	4	6	8	10
2	2.1730*	0.4523 ^{ns}	0.4854 ^{ns}	1.8430 ^{ns}
4		2.1469*	3.2120**	4.3964***
6			0.9196 ^{ns}	2.2039*
8				1.3937 ^{ns}

*: $p = 0.05$; **: $p = 0.01$; ***: 0.001.

Table IV shows the lactate levels obtained in the fourth phase study. Only the 4th and 6th min means are significantly different from each other.

TABLE IV: Blood lactate (mg%) at different intervals.
(n = 15)

Time (Recovery) (min)	AM	SD
4	72.4	7.42
5	70.9	8.56
6	65.1	14.78

DISCUSSION

The results obtained by the macro and micro methods and from venous and capillary blood are obviously well related to each other, and were connected by regression equations as follows :—

$$\text{Macro} = 1.0689 (\text{micro}) - 0.6291 \dots \dots \dots (1)$$

T (reg) = 45.65, significant at p = 0.001

$$\text{Ven.} = 0.9033 (\text{cap.}) + 0.1567 \dots \dots \dots (2)$$

T (reg) = 52.30, significant at p = 0.001

Combining both equations, we get

$$(\text{Macro, Ven.}) = 0.9655 (\text{Micro, Cap}) - 0.4366 \dots \dots \dots (3)$$

Attempts to fit exponential curves, or separate linear equations spanning lower and higher ranges did not improve the T (regression) value.

It may be seen from Table III-A that the highest blood lactate level was obtained after 4 minutes of recovery. This value is also significantly different from the 2nd and 6th min values (Table III-B). This is close to, but earlier than the time reported in literature (2,3). Thus, there was possibility that the peak occurred after the 5th minute. To investigate this, and to see whether non-exhaustive work changed this pattern, the fourth phase was undertaken. This clearly demonstrated that the peak occurred after the 4th minute, and that the pattern was independent of the heaviness of work (in the range studied).

CONCLUSION

It may be concluded that drawing a prewarmed fingertip blood sample 4 mins after end of work, analysing by the modified (micro) method, and using the regression equation will give an estimate of the true peak blood lactate level so as to satisfy the needs of occupational health practice, and within the limits imposed by the systems criteria defined.

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CONCLUSION