
The effect of exercise on intraocular pressure

I. Human beings

Daniel F. Marcus, Theodore Krupin, Steven M. Podos, and Bernard Becker*

Intraocular pressure, blood pH, plasma osmolarity, blood lactate, blood pyruvate, blood pressure, and pulse were monitored in 12 human subjects following exercise. Intraocular pressure was found to decrease after exercise. This decrease was associated with a rise of blood lactate and plasma osmolarity and a fall in blood pH. The fall in intraocular pressure after exercise was compared to that seen after sodium lactate infusion.

Key Words: exercise, human beings, intraocular pressure, acidosis, blood lactate, plasma osmolarity.

Physical exercise produced a decreased intraocular pressure without significant change in facility of outflow or episcleral venous pressure.¹⁻³ The diminution in intraocular pressure was associated with an increased serum osmolarity,³ but it was believed that this did not account completely for the change. The purpose of this investigation was to explore other

factors associated with the lowering of intraocular pressure after exercise.

Methods and materials

Twelve volunteers, six men and six women, ranging in age from 23 to 42, served as the subjects for these experiments. Subjects were untrained, had no ocular pathology, and were considered to be in average physical condition. Exercise was performed in the fasting state. Intraocular pressure was measured using the Goldmann applanation tonometer under topical anesthesia with proparacaine hydrochloride 0.5 per cent. Stasis-free heparinized venous blood samples were drawn for measurement of pH, osmolarity, lactate, and pyruvate. The pH was measured immediately on whole blood using an expanded scale Beckman pH meter at 37° C. Whole blood samples were then deproteinized with cold perchloric acid and the supernatant fluid was used for lactic and pyruvic acid determination with the lactate dehydrogenase enzymatic method (Sigma Chemical Company, St. Louis, Mo.). The remaining blood sample was centrifuged and osmolarity was determined on the plasma by freezing point depression using the Advanced Osmometer. Blood pressure and pulse

From the Glaucoma Center, Department of Ophthalmology, Washington University School of Medicine, St. Louis, Mo.

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Reprint requests: Dr. Bernard Becker, Department of Ophthalmology, Washington University School of Medicine, 660 S. Euclid Ave., St. Louis, Mo, 63110.

*Present address: Department of Ophthalmology, Marquette School of Medicine, Milwaukee, Wis.

were also measured. Exercise was performed on a treadmill jogger (Walton Manufacturing Company, Dallas, Texas) for four minutes and odometer readings were recorded. Subjects were instructed to exert maximal effort.

Baseline resting intraocular pressure, blood pressure, and pulse were recorded and a blood sample was taken. After exercise, intraocular pressure, blood pressure, and pulse were measured and blood samples were drawn immediately (within one minute) and at 15, 30, and 60 minutes.

In an attempt to simulate the rise in blood lactate induced by exercise, six fasting subjects received an intravenous infusion of 6 per cent sodium lactate. Baseline applanation tonometry was performed and a stasis-free, heparinized venous blood sample was obtained for blood pH, plasma osmolarity, and blood lactate determinations. Lactate solution (325 ml.) was administered over six minutes with repeat measurements obtained immediately (within two minutes), and at 15 and 30 minutes.

Statistics were analyzed using the paired-t test for individual subjects and Student's-t test when comparing group changes.

Results

Each subject completed four minutes of exercise on the treadmill. The degree of exertion was moderate; the average distance run was $1,095 \pm 97$ feet (mean \pm S.E.M.).

Table I lists the mean values for intraocular pressure, blood pH, plasma osmolarity, blood lactate and pyruvate, blood pressure, and pulse before and at various times after exercise. The average changes for these parameters are shown in Fig. 1.

The mean fall in intraocular pressure (5.9 mm. Hg) immediately after exercise was highly significant ($p < 0.001$). The

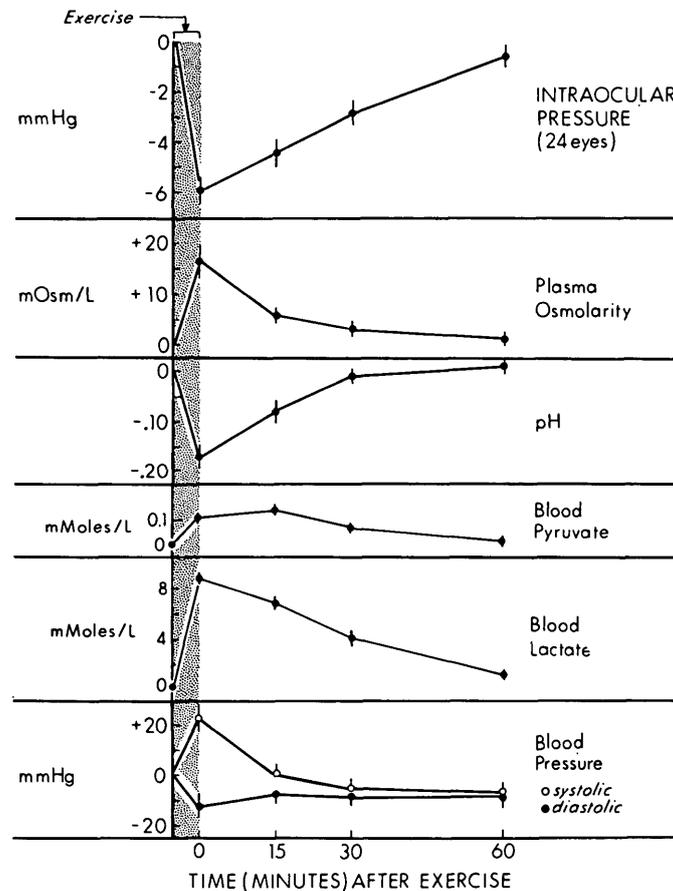


Fig. 1. Average changes for selected parameters (mean \pm S.E.M.) induced by exercise in 12 human subjects.

intraocular pressure was still below baseline at 30 minutes ($p < 0.001$) and returned to pre-exercise levels by one hour.

There was a peak rise in blood lactate immediately ($p < 0.001$) after exercise with a return toward baseline values during the hour. Immediately, and 15 minutes after exercise, there was a highly signifi-

cant ($p < 0.001$) increase in plasma osmolarity and fall in blood pH, with these parameters returning to baseline values at 30 minutes. Blood pyruvate was elevated during the 30 minutes following exercise with a return to baseline levels after 60 minutes.

Exercise resulted in an immediate increase ($p < 0.005$) in systolic blood pres-

Table I. Effect of exercise on intraocular pressure, pulse, blood pressure, blood pH, plasma osmolarity, blood lactate and blood pyruvate levels of 12 human subjects (mean \pm S.E.M.)

Characteristic	Baseline	Measurement after exercise (min.)			
		Immediately	15	30	60
Intraocular pressure (mm. Hg)	15.4 ± 0.5	9.5 ± 0.4	11.0 ± 0.5	12.6 ± 0.5	14.9 ± 0.5
Blood pH	7.36 ± 0.01	7.18 ± 0.02	7.27 ± 0.02	7.35 ± 0.01	7.37 ± 0.01
Plasma osmolarity (mOsm. per liter)	289 ± 2	305 ± 5	295 ± 2	292 ± 2	290 ± 2
Blood lactate (mmoles per liter)	0.8 ± 0.1	9.6 ± 0.8	7.6 ± 1.0	4.8 ± 0.6	1.8 ± 0.2
Blood pyruvate (mmoles per liter)	0.09 ± 0.01	0.20 ± 0.02	0.23 ± 0.02	0.16 ± 0.01	0.11 ± 0.01
Systolic blood pressure (mm. Hg)	111 ± 3	135 ± 7	111 ± 3	106 ± 3	105 ± 4
Diastolic blood pressure (mm. Hg.)	77 ± 3	65 ± 3	70 ± 3	68 ± 3	69 ± 3
Pulse (beats per minute)	82 ± 2	152 ± 5	101 ± 5	97 ± 5	88 ± 4

Table II. Effect of intravenous sodium lactate on intraocular pressure, blood pH, plasma osmolarity, and blood lactate levels of six human subjects (mean \pm S.E.M.)

Characteristic	Baseline	Measurement made after infusion (min.)		
		Immediately	15	30
Intraocular pressure (mm. Hg)	13.2 ± 0.7	10.0* ± 0.4	8.6* ± 0.5	10.2* ± 0.6
Blood pH	7.36 ± 0.02	7.47* ± 0.03	7.48* ± 0.04	7.42* ± 0.03
Plasma osmolarity (mOsm. per liter)	283 ± 3	294* ± 4	292* ± 6	292* ± 3
Blood lactate (mmoles per liter)	0.8 ± 0.1	7.6* ± 0.6	3.4† ± 0.6	2.4* ± 0.2

*Significant difference between initial value versus value at designated time, $p < 0.005$.
†Significant difference between initial value versus value at designated time, $p < 0.025$.

sure and a decrease in diastolic blood pressure ($p < 0.01$). The systolic blood pressure returned to baseline levels by 15 minutes while the diastolic pressure remained depressed throughout the hour ($p < 0.025$). The pulse rate was significantly ($p < 0.001$) increased immediately after exercise and did not return to pre-exercise levels until 60 minutes.

Table II lists the effects of sodium lactate infusion on intraocular pressure, plasma osmolarity, blood lactate, and blood pH in six volunteers. Intraocular pressure was significantly ($p < 0.001$) decreased up to 30 minutes after infusion, with the maximum decrease occurring at 15 minutes. The maximum increase in blood lactate of 7.6 mM. per liter was observed immediately with gradual return to preinfusion levels. Plasma osmolarity rose 15 mOsm. per liter maximally at 15 minutes. An increased blood pH was associated with the sodium lactate infusion.

Discussion

The present study confirms the fall in intraocular pressure in human beings seen after exercise.¹⁻³ There is a significant rise in blood lactate, a concomitant increase in plasma osmolarity, and a lowering of blood pH. The maximum fall in intraocular pressure and changes in blood chemistries occur immediately following exercise. At 30 minutes, blood pH and plasma osmolarity return to baseline levels, while blood lactate is still elevated and intraocular pressure is still decreased. These changes in blood chemistry after exercise are similar to other reported studies.⁴⁻⁶

The change in blood lactate immediately after sodium lactate infusion does not differ significantly from the change after exercise. However, the intraocular pressure fall immediately after infusion is not as great. The increase of plasma osmolarity is greater immediately after exercise and is associated with a decrease in blood pH. The respective contributions of these two factors cannot be separated in this study. The increase in blood lactate

immediately after exercise does not account for the entire observed increase in plasma osmolarity. Other factors, such as hemoconcentration and dehydration, account for the greater osmolarity rise seen after exercise.⁷ Studies have shown that acidosis lowers intraocular pressure.^{8, 9} In exercise, lactate levels are the result of lactic acid production with its accompanying acidosis. The greater fall in intraocular pressure after exercise compared to the decrease seen in lactate infusion may be explained by this associated acidosis. An animal model is presently being studied to further elucidate the mechanism of the fall in intraocular pressure seen after physical exertion.¹⁰

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