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Blood Lactic Acid After Exercise with Particular Reference to Polycythemia Rubra Vera.

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Under normal resting states the concentration of lactic acid in venous blood of normal human beings varies from 10 to 20 mg per 100 cc of blood where the Friedman Contonio and Shaffer method is used. (Peters and Van Slyke).[1] When normal individuals are submitted to mild exercise* a slight rise of the lactic acid concentration above the resting level occurs. (Table I.) The average concentration of the lactic acid values was 13.9 mg per 100 cc at rest while after mild exercise it rose to 16.3 mg per 100 cc of blood, an average increase of slightly more than 2 mg per 100 cc. In no instance did the lactic acid concentration exceed 21 mg %. In these 11 cases the hemoglobin concentration and red blood counts were in the normal range.

In Table II we have recorded the resting and post exercise values of the blood lactic acid in 5 normal individuals with high hemoglobin

TABLE I.
Lactic Acid Content of Venous Blood During Rest and After Exercise in Normal Subjects.

Case	Age	Sex	Amount of work performed kg	Lactic acid (mg per 100 cc) before	after
1	22	Female	1,260	12.8	15.0
2	23	Male	1,440	10.3	12.9
3	11	Female	1,050	13.6	16.6
4	19	"	1,287	11.4	13.7
5	13	Male	1,350	15.0	17.0
6	24	"	1,920	15.8	16.4
7	13	Female	1,092	12.6	16.8
8	59	Male	2,000	15.3	20.5
9	10	Female	350	12.0	17.2
10	24	Male	1,700	15.4	15.8
11	35	"	1,500	17.7	17.8
			Avg	13.8	16.3

[1] Peters, J. P. and Van Slyke, D. D., *Quantitative Clinical Chemistry*, Vol. I, Williams and Wilkins Co., 1932.

* The exercise test consisted of having the subject step on and off a stool exactly one foot high. The duration of the exercise varied from 4 to 6 minutes depending upon the number of steps the subject was obliged to take in order to complete the required amount of work.

TABLE II.
Lactic Acid Levels of Venous Blood Before and After Exercise in Normal Individuals with High Red Counts and Hemoglobin Contents.

Case	Age	Sex	Work performed, kg	Lactic acid, mg %		Hgb.	RBC million
				before	after		
1	23 (JF)	Male	1,526	19.06	21.44	111	5¾
2	27 (CG)	"	1,560	12.01	12.35	108	6
3	21 (DS)	"	1,440	16.25	19.34	99	5
4	25 (RK)	"	1,530	12.20	12.83	106	5
5	30 (AM)	"	1,600	16.32	20.63	108	5
6	26 (WS)	" (diabetic)	1,520	19.58	22.26	105	5½
			Avg	15.0	17.3		

and red counts including one diabetic with a high hemoglobin and red blood count. Excluding the latter the average resting value as well as the average values following exercise are higher than those in the normal range. As in normals a slight but definite rise in the lactic acid concentration takes place, going from an average resting value of 15 mg % to 17.3 mg %, an average increase of slightly over 2 mg %. From this it is evident that normal individuals with high hemoglobin contents and high red blood counts show essentially the same lactic acid response to exercise as normal individuals.

Extreme grades of secondary polycythemia may often be found in association with morbus caeruleus type of congenital heart disease, where the direction of the shunt is venous-arterial. Table III shows the lactic acid response to exercise in those cases of congenital heart disease with cyanosis, where in some cases polycythemia was one of the outstanding features.

It will be noted from the Table III, that in some instances the lactic acid concentration doubles itself after exercise. However, a consistent rise of the blood lactic acid is found in all cases. The polycythemia of congenital heart disease appears to be a compensatory process arising from the stimulation of erythropoietic tissue of bone marrow, in an attempt to reduce the oxygen deficit by providing more hemoglobin and red cells.

The polycythemia found in extreme cases of emphysema is likewise regarded as a compensatory process to combat anoxemia. In Table IV we have recorded the lactic acid response to exercise in emphysema. Cases 1 and 2 showed a slight polycythemia. Here again we see a rise in lactic acid, but not so great as seen in morbus caeruleus.

We next investigated the lactic acid response to exercise in cases of polycythemia rubra vera. We have studied 9 cases (Table V). All of

TABLE III.
Lactic Acid Levels of Venous Blood Before and After Standard Exercise in Those Cases of Congenital Heart Associated with Venous-Arterial Shunts.

Case	Age	Sex	Diagnosis	Work performed, kg	Lactic acid, mg % before	Lactic acid, mg % after	Hgb. %	RBC m.
11	63	Male	Intervent. septal defect	1200	18.44	43.25	121	7½
12	19	"	Tetralogy of Fallot	540	17.98	40.94	106	11
13	17	Female	" " "	1350	16.03	28.44	132	7½
14	23	"	Patent ductus	875	13.20	28.68	90	5
14	23	"	" "	984	13.30	27.54		
15	21	"	Intervent. septal defect probably associated with patent ductus	1475	20.88	47.10	82	5
15	21	"	Intervent. septal defect probably associated with patent ductus	1720	18.48	29.56		
16	25	Male	Intervent. septal defect with patent ductus	1512	20.78	22.01	130	7
16	25	"	Intervent. septal defect with patent ductus	1800	18.85	22.57		
				Avg	17.5	32.2		

TABLE IV
Lactic Acid Levels of Venous Blood Before and After Exercise in Emphysema.

Case	Age	Sex	Amount of work kg	Lactic acid, mg % before	Lactic acid, mg % after	Hgb.	RBC million
1	60 (MM)	Male	1409	17.9	20.1	104	5
2	51 (H)	"	819	20.5	24.7	105	5½
3	41 (MLM)	"	1320	21.2	22	86	4½
			Avg	19.8	22.2		

these patients exhibited the classic clinical picture of polycythemia rubra vera. The diagnoses were verified by blood studies, mainly hemoglobin concentration, red blood cell count, hematocrit readings and blood volume determinations. It will be noted that a most unusual lactic acid response develops following mild exertion. Instead of the blood lactate increasing as it does in normals, and in other types of secondary polycythemia, we find in these cases on exercise an actual decrease in the lactic acid concentration of the blood. The average resting blood lactate value is 17.8 mg %, while following exercise it declines to 15.1 mg %, an average decrease of 3 mg %. This decrease was found to be consistent in all cases. That the decrease in the concentration of the blood lactate is not dependent on the height of the hemoglobin and red blood cell content of the blood, is indicated in case 8. This patient was first admitted to the University Hospital in 1930, and a diagnosis of polycythemia rubra

TABLE V.
Lactic Acid Levels of Venous Blood Before and After Exercise in Polycythemia Rubra Vera.

Case	Age	Sex	Work performed, kg	Lactic acid, mg % before	Lactic acid, mg % after	Hgb. %	RBC m.	B.V.	Hct. %
1	45 (P)	M	1,440	19.2	14.1	112	8		
2	55 (ER)	M	1,526	16.4	14.1	110	6		
3	49 (JS)	M	1,700	18.6	15.6	114	7¼	7.0 L.	65
3 (a)			3,000	16.4	15.3	99	5¼		
			(following phenylhydrazine therapy)						
4	51 (ME)	Fe	1,300	20.1	17.4	100	6¾	5.2 L.	66
5	30 (MC)	M	1,585	19.0	13.3	122	6		
6	49 (JM)	M	1,500	15.4	12.9	129	6¼	8.1 L.	64
7	27 (EH)	M	1,550	18.2	16.7	101	5	6.2 L.	55
7 (a)			3,000	16.2	15.6	99	6		
8	50 (AP)	Fe	1,400	19.2	16.3	78	4¾	4.3 L.	41
			(myelogenous leukemia)						
9	24 (ML)	M	1,560	22.1	17.5	126	7	6.1 L.	65
9 (a)			2,000	13.9	12.7	90	4¾		50
			(spontaneous remission)						
			Avg	17.8	15.1				

vera was made. The hemoglobin at that time was 120%, and the red blood count 7.5 millions. She was referred to the University Hospital for further study in March, 1938, because of anemia and progressive enlargement of the spleen. On this second admission, she was found to have myelogenous leukemia, a complication which not infrequently follows from polycythemia rubra vera.[2] Her hemoglobin now was 78% and red blood count 4.5 millions.

When this patient was submitted to the lactic acid test, a typical drop in the blood lactate occurred. This case is extremely instructive, inasmuch as the blood lactic acid values indicate that the polycythemic state is not necessary to produce the drop in the blood lactate. This observation was further corroborated in cases of polycythemia rubra vera whose hemoglobin and red blood count levels were lowered to within the normal range by the therapeutic administration of phenylhydrazine. Case 3 is such an example.

The lactic acid response was obtained before treatment, when the hemoglobin was 114% and the red blood count 7.5 millions. The patient was then treated with the drug and the hemoglobin and red blood count brought down to 99% and 5.5 million cells respectively [3(a)]. The same response was again noted, namely a lowering of the blood lactate level after exercise. Case 9 also illustrates the

[2] Minot, G. R., and Buchman, T. E., *Am. J. Med. Sciences*, October, 1923, **166**, 469.

same point [see 9(a)]. Furthermore the drop in the lactic acid level was obtained when patients with true polycythemia were submitted to more strenuous exercise. Thus, as indicated in Table V, when patients 3, 7 and 9 were submitted to increased work 3(a), 7(a), and 9(a), the same response was still obtained. From these observations we can conclude that the hemoglobin and red blood count level is not the factor which is responsible for the decrease in the blood lactate level in true polycythemia, inasmuch as the response is still obtained at lower ranges.

It is believed that these observations indicate that at rest, the blood flow, particularly through the muscles and perhaps certain glands producing lactic acid, is diminished below normal levels, and that anaerobic metabolic processes lead to the accumulation of abnormal amounts of lactic acid in the blood. With mild exercise the blood flow through muscle is greatly increased and the oxygen supply raised enough to prevent the lactate production. This view is supported by the additional observation that a polycythemic patient responded to a hot bath of 15 minutes' duration by a decrease in blood lactic acid. The fact that the same response occurs in the polycythemia rubra vera patient after reduction of the red cell count to normal, as when the count was elevated, indicates that the disturbance in lactate metabolism is dependent upon some primary factor such as a vasoconstriction, to which the polycythemia is itself secondary. These results seem to indicate, therefore, that tissue anoxia may be an important link in the chain of pathological processes involved in polycythemia vera, and that the primary disturbance may be a persistent vasoconstriction in certain tissues.

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Artificially Produced Anoxia as a Means of Demonstrating Abnormal Respiratory Function.

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A considerable degree of pulmonary collapse can be maintained in man with very little alteration of respiratory function other than an abnormal amount of hyperventilation on exertion. Latent physio-