

**THE EFFECT OF MUSCULAR EXERCISE ON THE
OXYGEN CAPACITY OF THE BLOOD OF MAN.**

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IN the course of some studies of muscular activity at low oxygen pressures we have had occasion to study the oxygen content of the blood. Before and during exercise blood was drawn from the dorsum of the hand which was immersed in water warmed to 45–47° C. Goldschmidt and Light⁽¹⁾ and Mrs Kerridge⁽²⁾ have shown that blood obtained in this way approaches arterial blood in composition. The exercise consisted in alternately sitting and rising to the erect position at a rate of approximately 30 times per min. In some of the experiments the subject breathed air; in others the inspired gas was an air-nitrogen mixture containing 10–15 p.c. oxygen. The oxygen content and capacity of the blood were determined by the method of Van Slyke and Neill⁽³⁾.

TABLE I. Oxygen content and capacity of blood during rest and exercise.

Date	Subject	p.c. O ₂ in gas	Rest			Exercise		
			O ₂ cap.	O ₂ cont.	p.c. sat.	O ₂ cap.	O ₂ cont.	p.c. sat.
March 26	S.	12.00	16.85	12.20	72.4	19.21	16.72	87.0
April 4		12.25	16.53	16.06	97.0	17.81	15.25	86.0
„ 6		11.36	17.28	14.95	86.5	17.82	12.91	72.4
„ 10		20.93	16.52	16.08	97.4	17.63	17.32	98.3
„ 10		20.93	(16.73)	(16.20)	(96.9)	—	—	—
May 4		12.50	—	14.11	73.4	20.09	13.75	68.6
„ 4		12.50	(19.26)	(15.52)	(80.6)	—	—	—
„ 8		20.93	18.39	17.37	93.6	18.79	18.05	96.2
March 28	R.	—	22.48	18.18	80.8	23.66	20.56	86.7
April 5		11.36	22.39	18.85	84.2	23.34	17.81	76.6
„ 23		13.00	20.62	17.12	82.9	21.30	15.30	71.2
„ 23		13.00	—	(18.05)	(87.5)	—	—	—
May 7		20.93	21.39	20.75	97.1	21.31	21.12	99.1
„ 9		10.50	21.75	16.44	75.6	22.08	16.20	73.4
„ 9		10.50	(21.68)	(16.51)	(76.2)	—	—	—
„ 17		20.93	21.42	20.00	93.3	21.78	21.02	96.5
March 27	I.	11.80	20.54	15.38	75.0	20.28	16.50	80.9
March 28	L.	14.92	20.05	18.95	94.6	20.92	19.95	95.4

Note. Figures in parenthesis are for blood obtained by arterial puncture. Samples for other figures were taken from the hand immersed in hot water.

The results of the experiments are shown in Table I. The most constant finding was an increase during exercise of the oxygen-carrying power of the blood. This occurred in 12 of 14 experiments, amounting usually to somewhat less than 1.00, but in one case rising to 2.36 volumes p.c. In the subject S. the increase was approximately the same whether air or an oxygen-poor mixture was breathed. With R., on the other hand, the rise in oxygen capacity induced by exercise appears to be greater when anoxemia is present.

The data on the oxygen saturation of the blood are less uniform than those dealing with oxygen capacity. Our findings when the subject breathed air confirm those of other investigators, that the blood obtained from the veins of the hand immersed in hot water has approximately the same oxygen content as has the true arterial blood. However, when the subject breathes a gas mixture containing 10–15 p.c. oxygen, the blood from the hand veins may have a distinctly lower oxygen content than the true arterial blood. This phenomenon is of some interest as it suggests that the observation made on dogs by Bronk and Gesell⁽⁴⁾, namely that there is increased carotid and decreased femoral flow during anoxemia, may also apply to man. Schneider and Truesdell⁽⁵⁾ measured the blood flow through the hand during anoxemia and found a decrease. Barcroft, Bock and Roughton⁽⁶⁾ found that the circulation through the hand was greatly decreased in a case of paroxysmal tachycardia. On the other hand, Harrison and his co-workers⁽⁷⁾ found the total blood—minute cardiac output—of normal, unanæsthetised dogs to be increased when the arterial blood is less than 75 p.c. saturated. Our findings, as well as those mentioned above, suggest that the circulatory compensation to anoxemia consists in changes in distribution as well as in the amount of blood flow.

Because of the close agreement between our values for arterial and hand blood while the subject breathed air, we are inclined to place confidence in our results, which indicate that during exercise while breathing air there is a tendency for the saturation to be somewhat greater than at rest. Eppinger, Kish and Schwarz⁽⁸⁾ have reported similar observations. Harrop⁽⁹⁾ has also studied this subject. But when the subject breathed oxygen-poor mixtures the findings concerning percentage saturation were variable, and since the hand blood may be as much as 5 p.c. less saturated than the true arterial blood, we are not inclined to attach great significance to our figures for arterial saturation during anoxemia. The data as they stand indicate that the arterial saturation may increase but usually decreases during exercise at low oxygen

pressures. In order to be certain of this point it is necessary to obtain blood from the artery during exercise, and this we have not been able to do.

At present we are unable to make any definite statement as to the cause of the increase in the oxygen capacity. In addition to the many workers who have studied the osmotic pressure of excised muscle it was shown by Barcroft and Kato⁽¹⁰⁾ on mammalian muscle, and by Back, Cogan and Towers⁽¹¹⁾ on frog's muscle, that a muscle provided with an efficient circulation gained in weight on continued stimulation, imbibing water presumably from the circulation through its vessels. On the other hand, recent work on the spleen suggests that the rise in oxygen capacity during exercise is in part, at all events, due to the contraction of the spleen inasmuch as a similar rise in animals is reduced or abolished by splenectomy. In the horse and dog, where the rise in oxygen capacity is much greater than in man, the experiments of Scheunert and his associates⁽¹²⁾ yielded evidence of combined splenic and osmotic effect.

Since the completion of these experiments and while this report was in preparation a paper by Bock, Vancaulaert, Dill, Fölling and Hurxthal⁽¹³⁾ has appeared. These investigators also found an increase in the oxygen capacity of the blood of human subjects during exercise.

SUMMARY.

1. Blood from the hand veins after immersion in water at 45° is indistinguishable in oxygen content from arterial blood while the subject is breathing air.

2. It is not indistinguishable but is of slightly lower oxygen content in anoxemia.

3. The oxygen capacity is increased during exercise while the subject breathes either air or an oxygen-poor mixture.

4. The oxygen saturation of the arterial blood sometimes goes up and sometimes down during exercise in air, but more often it goes up.

In conclusion we wish to express our thanks to Prof. Barcroft for his interest and advice.

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