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Tornow[1] found in experiments on soldiers before and after long marches that the red corpuscles in the capillary blood of the ear increased about 9 per cent and the white about 43 per cent. He considered that this increase in the red cells corresponded roughly to the increased density of the blood as a result of the sweat caused by the muscular work.

Some years later (1908) Hasselbalch and Heyerdahl[2] in a large series of experiments dealing with the effect of work on the increase in the number of leucocytes performed two experiments in which they determined the effect on the number of red cells. In both of these experiments they found an increase in the red corpuscles; in one ("Exp. 59"), there was a 17 per cent, and in the other ("Exp. 60"), a 13 per cent increase. The details of these two experiments are shown in Table I.

In neither of these experiments is there a definite reaction after the first run, while after the second run there is in both experiments a very distinct rise in the number of red blood corpuscles. This can be explained on the ground that there was no distinct change in the relative number of red cells until sufficient time had elapsed for an appreciable amount of sweating to have occurred.

[1] Tornow: Quoted by Hasselbalch and Heyerdahl, loc. cit., p. 291.

[2] Hasselbalch and Heyerdahl: Uber einige physische Ursachen zu Schwankungen der Menge von Blutkorperchern. Skand. Arch. f. Physiol., 1907–1908, xx, 289–329.

In view of these findings it is evident, at least in certain subjects, that work causes a change in the oxygen carrying capacity of the blood. Therefore, in order to calculate properly the percentage saturation of the haemoglobin in the venous blood in a series of experiments being done in this laboratory on the determination of the blood flow at rest and at work, it was necessary for us to verify the above findings and to determine the order of the variation in the subject of the blood flow experiments.[3]

TABLE I

EXPER. NO.	TIME	POSITION.	PULSE	RED CORPUSCLES.	INCREASE
				per cu. mm.	*per cent*
59	10.10	Lying down	66	5,281,000	
59	10.17	Lying down after a sharp run		5,471,000	
59	11.23	Lying down	72	5,611,000	
59	11.34	Lying down after a second sharp run	128	6,354,000	17
60	9.30	Lying down	68	5,864,000	
60	9.40	Standing after a sharp run	130	5,717,000	
60	10.30	Lying down	80	5,554,000	
60	10.40	Standing after a second sharp run	138	6,487,000	13

For the determination of the haemoglobin use was made of the Haldane-Gowers haemoglobinometer and the colorimetric readings were controlled by Mr. H. F. Aitken, artist to Dr. Cushing.

The number of red corpuscles was determined in the usual way by counting and taking the average of four fields.

Before taking the samples of blood for determining the normal or resting value, the subject sat down for about five or ten minutes and care was taken that this period was preceded by only light laboratory work.

[3] Boothby: A determination of the circulation rate in man at rest and at work. The regulation of the circulation. This Journal, 1915, xxxvii.

For determining the effect of work, the subject mounted a stationary bicycle and peddled for one-half hour before the blood sample was taken. During the latter part of the work period the subject exercised his arm and hand muscles in order that the blood sample would be obtained from an actively circulating blood current. In some of the experiments the respiratory exchange was determined just before taking the blood sample, in order to find the oxygen consumption per minute and thus have a quantitative expression of the amount of work done.

The results of the experiments are given in Table III at the end of the paper. In Table II are given the averages for each individual.

TABLE II

SUBJECT	HAEMOGLOBIN			RED CORPUSCLES		
	Rest	Work	Increase	Rest	Work	Increase
			per cent			*per cent*
W. M. B.	120	121	0	6,320,000	6,404,000	0
F. B. B.	101	108	7	6,283,000	7,333,000	17
H. F. A.	112	124	11	5,164,000	5,920,000	15
W. B. Y.	112	123	10			
J. W. W.	117	130	11			
F. G. W.	123	135	11	5,784,000	7,224,000	25

In W. M. B. no appreciable change occurs in the values found at rest and after work for either the percentage of haemoglobin or the number of red cells. In the other subjects there is a distinct rise in the haemoglobin percentage in all but one of the work experiments on F. B. B.; the determination of the red blood corpuscles followed in a general way the increase in the haemoglobin percentage, although the percentage increase appeared distinctly larger. The subject W. M. B., in whom no demonstrable change occurred either in the haemoglobin percentage or in the number of red corpuscles after work, perspires very little even in extremely warm weather. Under the conditions of the experiments, as here carried out, no appreciable amount of perspiration was formed and the skin remained dry during the entire experiment. Likewise in the experiment on F. B. B. on

September first in which no change occurred in the haemoglobin percentage, the subject had not started to perspire when the blood sample was taken; fifteen minutes later the number of red blood cells showed a distinct increase and by this time the subject was perspiring very freely. In all the other experiments the subjects always perspired freely.

Our experiments which show an increase in the haemoglobin percentage and the number of red blood corpuscles, whenever the work performed caused the subject to perspire, substantiate the theory suggested by Tornow that the increase in the number of the red blood corpuscles, which he found in soldiers after long marches, was due to an increase in the density of the blood as a result of the sweat thereby produced.

On account of the rise in the haemoglobin percentage the oxygen carrying capacity per unit volume of blood is proportionately increased. It is another interesting example of the intercompensatory mechanism of the human body; it is evident that, in the main, the object of perspiration is to keep the body temperature down under conditions of work, yet its formation and elimination, by increasing the proportion of haemoglobin, increases the carrying capacity of a unit volume of blood thereby throwing less strain on the circulatory system.

It is obviously necessary, therefore, to determine under the actual experimental conditions the haemoglobin present in work experiments the object of which is to determine such factors as the oxygen carrying capacity of the blood, the coefficient of utilization of the oxygen per unit of blood, or in accumulating evidence for or against the secretory theory of oxygen, or other problems of like nature.

SUMMARY

Experimental data are given showing that the percentage of haemoglobin and the number of red blood corpuscles, and therefore the oxygen carrying capacity of a unit volume of blood, are increased under conditions of work, causing an appreciable amount of perspiration. If no perspiration occurs there is no such increase.

TABLE III

DATE	SUBJECT	REST			WORK			INCREASE	
		O_2 Consumption	Haemoglobin	Red Corpuscles	O_2 Consumption	Haemoglobin	Red Corpuscles	Haemoglobin	Red Corpuscles
		cc. per min.	*per cent*	*per cu. mm.*	*cc. per min.*	*per cent*	*per cu. mm.*	*per cent*	*per cent*
Aug. 6	W. M. B.	(185)	120		1165	120			
Aug. 10	W. M. B.	(185)	120		924	120			
Aug. 13	W. M. B.	(185)	118	6,440,000					
Sept. 10	W. M. B.	(185)	123	6,200,000	(1000)	124	6,404,000		
			120	6,320,000		121	6,404,000	0	0
Aug. 7	F. B. B.	(225)	99		934	100			
Aug. 12	F. B. B.	(225)	99						
Aug. 14	F. B. B.	(225)	99		2289	111	7,832,000		
Aug. 15	F. B. B.	(225)	99		1946	100[1]	8,416,000		
Aug. 15	F. B. B.	(225)	99						
Aug. 15	F. B. B.	(225)				107[2]			
Aug. 17	F. B. B.	(225)	99		1934	112	7,208,000		
Aug. 18	F. B. B.	(225)	102		2164	111	6,080,000		
Aug. 21	F. B. B.	(225)	102						
Aug. 21	F. B. B.	(225)	102	6,048,000					
Aug. 22	F. B. B.	(225)		6,530,000					
Sept. 1	F. B. B.	(225)	101	6,272,000		101[3]			
Sept. 1	F. B. B.	(225)					7,280,000[4]		
Sept. 4	F. B. B.	(225)	102			110	7,184,000		
Jan. 15	F. B. B.	(225)	104			110			
			101	6,283,000		108	7,333,000	7	17
Sept. 11	H. F. A.		112	5,164,000	(1500)	124	5,920,000	11	15
Jan. 28	W. B. Y.		112			123		10	
Jan. 28	J. W. W.		117			130		11	
Jan. 28	F. G. W.		123	5,784,000		135	7,224,000	11	25

[1] Haemoglobin turned slightly brown (not averaged).
[2] Sample taken 50 minutes after work stopped.
[3] Subject not perspiring when blood sample was taken.
[4] Sample taken 15 minutes after haemoglobin sample.

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