

*THE EFFECT OF POSTURE UPON THE COMPOSITION AND VOLUME OF THE BLOOD IN MAN*BY WILLARD OWEN THOMPSON,<sup>1</sup> PEHBE K. THOMPSON<sup>2</sup> AND MARY ELIZABETH DAILEY

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Measurements have been made to determine the composition and volume of the blood in man in the recumbent and in the standing still positions. These measurements are summarized in table 1.

It may be seen that during the period of standing still,<sup>3</sup> after a rest in the recumbent position, there are the following changes in the blood:

1. An increase in the number of red cells per cu. mm. of blood (I).
2. A corresponding increase in the volume of red cells per liter of blood (II).
3. An increase in the concentration of plasma protein (IV).
4. An increase in the specific gravity of plasma (VI).
5. A decrease in the concentration of plasma water (V).
6. A decrease in the total amount of plasma in the blood of the whole body (III).

Observations on the mixing of a dye, according to a slight modification (1) of the usual method employed in estimating plasma volume, have been made and are summarized on a typical case in tables 2 and 3. These data show two significant things:

1. A much longer time is required for the dye concentration in the blood to become uniform all over the body in the standing still position than in the recumbent position.
2. When the concentration has become uniform, it is always greater in the standing still position than in the recumbent position.

Confirmatory evidence of the effect of posture upon plasma volume may be found in the hematocrit measurements of cell volume recorded in table 4.

From these observations, it seems safe to draw the conclusion that, while standing still, there is temporarily a much greater loss of fluid from the blood than gain to it through the thoracic duct and other sources.

Assuming that the fluid lost is protein free, the changes in red cell count, plasma protein and plasma water calculated from the changes in total plasma volume correspond well with the actual observations (table 5). Moreover, the total cell volume for each subject, calculated from the total plasma volume and the cell percentage, is the same in both the recumbent and standing still positions (table 6).

The reciprocal relation between the protein and water changes is shown in figure 1.

These facts are consistent with the hypothesis that there has been on the average a net loss of 110 cc. of protein free fluid per liter of plasma, or a total loss of 290 cc., and no other change.

Upon resuming the recumbent posture the changes are reversed. The maximum fluid loss, which occurs in the standing still position in 20-30 minutes, is made up in about the same time in the recumbent position.

Most of the changes in the composition of the blood here noted are known to occur in the venous blood of an extremity as a result of raising the venous pressure (2), (3), (4), (5). Moreover, it has been demonstrated that, in

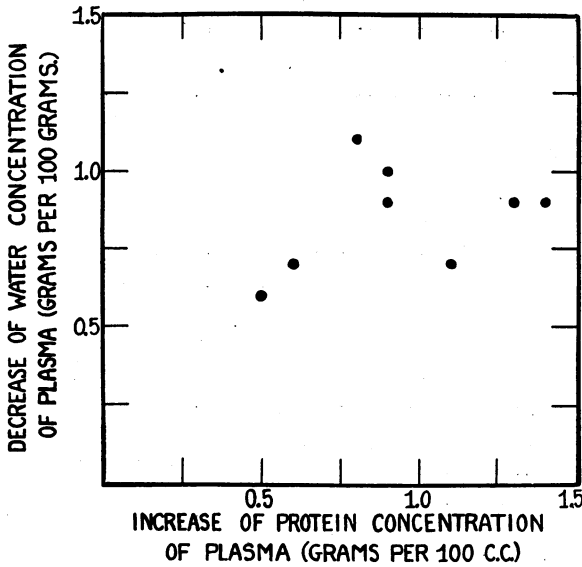


FIGURE 1

Increase in plasma protein concentration and decrease in plasma water concentration following change from the recumbent to the standing still position. (Table 1.)

the standing still position, the return of blood from dependent portions of the body is markedly retarded, (6), (7), and that the venous and capillary pressures in these parts are raised (8), (9), (10). These facts, already known, seem to offer a satisfactory explanation of the present observations.

*Conclusion.*—In the standing still position there occurs a net loss of approximately protein-free fluid from the blood. This seems to be due to an increase in capillary pressure. The loss amounts, on the average, to about 11 per cent of the total plasma volume, and is probably greatest where the filtration pressure is most increased, viz., in the lower extremities.

TABLE 1

CASE NO.	AGE	SEX	I RED BLOOD CELL COUNT (MLNS./CU. MM.)			II CC. OF CELLS PER 100 CC. OF BLOOD			III TOTAL PLASMA VOLUME (CC.)*			IV PROTEIN (GRMS./100 CC.)			V PLASMA WATER (GRMS./100 GRMS.)			VI SPECIFIC GRAVITY			
			LY- ING	STAND- ING	DIFF.	LY- ING	STAND- ING	DIFF.	LY- ING	STAND- ING	DIFF.	LY- ING	STAND- ING	DIFF.	LY- ING	STAND- ING	DIFF.	LY- ING	STAND- ING	DIFF.	
1	55	♂	4.8	5.7	+0.9	44.6	49.6	+5.0	3055	2580	-475	7.2	8.3	+1.1	91.1	90.4	-0.7	1026	1029		
2	60	♂	4.4	4.4	0.0	45.9	48.8	+2.9	2770	2445	-325	8.0	6.9	-1.1	91.5	90.6	-0.9	1026	1027		
3	38	♀	4.1	4.6	+0.5	40.1	44.2	+4.1	2140	1900	-240	7.0	7.8	+0.8	91.9	90.8	-1.1	1025	1029		
4A†	37	♀	3.9	4.3	+0.4	35.6	38.0	+2.4	2495	2160	-335	6.5	7.9	+1.4	91.3	90.4	-0.9	1028	1029		
5	31	♂	4.7	5.1	+0.4	47.8	50.9	+3.1	2505	2160	-345	6.1	7.0	+0.9	92.2	91.3	-0.9				
6	43	♀	4.1	4.6	+0.5	28.1	30.2	+2.1	2755	2485	-270	6.1	7.0	+0.9	92.2	91.3	-0.9				
7	29	♀							1810	1580	-230	7.0	7.5	+0.5	91.3	90.7	-0.6				
8	28	♂							3200	2985	-215	7.2	7.8	+0.6	91.2	90.5	-0.7				
4B	37	♀							2495	2305	-190	7.2	7.8	+0.6	91.2	90.5	-0.7				
9	59	♂							2835	2525	-310	7.3	8.2	+0.9	91.0	90.0	-1.0				
Average for cases 1-6 inclusive			4.3	4.8	+0.5	40.3	43.6	+3.3	2620	2295	-325										
Average for cases 3-6 inclusive			4.2	4.7	+0.5	37.9	40.8	+2.9	2475	2185	-290	6.9	8.1	+1.2	91.5	90.6	-0.9	1026	1028		
Average for cases 3-9 inclusive												6.9	7.8	+0.9	91.4	90.6	-0.8				
Average plasma volumes for all cases									2605	2315	-290										

Nearly every determination recorded is the average of two or more measurements.

† Case numbers 4A and 4B refer to two distinct sets of experiments on the same subject.

\* In cases 1 to 6, inclusive, all plasma volumes were determined by the dye method. In cases 7, 8, 4B and 9, the plasma volume for the standing still position was calculated from the change in protein concentration. In cases 7 and 8, it was arbitrarily assumed to be 40 cc. per kg. for the recumbent position, and in cases 4B and 9 it was measured for this position by the dye method.

**TABLE 2**  
**EFFECT OF POSTURE UPON THE CONCENTRATION OF A DYE INJECTED INTRAVENOUSLY**  
 (Case 1)

POSITION OF BODY	AVERAGE CONCENTRATION OF DYE* IN PLASMA AFTER COMPLETE MIXING		
	RIGHT ARM VENOUS BLOOD %	LEFT ARM VENOUS BLOOD %	FOOT VENOUS BLOOD %
Lying down	101.1	99.9	99.6
Standing still	119.1	116.9	120.4

\* The average plasma volume for the recumbent position, viz., 3055 cc., has arbitrarily been chosen to represent 100 per cent concentration of dye.

**TABLE 3**  
 A FEW ILLUSTRATIVE EXPERIMENTS ON CASE 1 SHOWING THE EFFECT OF POSTURE UPON THE MIXING WITH BLOOD OF INTRAVENOUSLY INJECTED BRILLIANT VITAL RED

DATE	OF ASSUMING POSITION	TIME OF DYE INJECTION	OF OBSERVATION	CONCENTRATION OF DYE* IN PLASMA IN THE VENOUS BLOOD OF		
				RIGHT ARM %	LEFT ARM %	FOOT %
Lying Down						
5/ 7/27	9.00 A.M.	1.30 P.M.	1.35 P.M.	99.2		98.9
5/17/27	10.30 A.M.	1.00 P.M.	1.06 P.M.	103.0	101.9	102.1
6/ 9/27	11.00 A.M.	2.06 P.M.	2.11½ P.M.	98.9	98.0	97.5
			2.19 P.M.	98.4	97.7	96.9
Standing Still						
6/ 7/27	1.09 P.M.	1.17 P.M.	1.23 P.M.	123.0	115.8	101.1
			1.31½ P.M.	121.0	117.1	119.6
			1.48 P.M.	116.9	115.0	120.2
6/16/27	2.58 P.M.	3.12½ P.M.	3.19½ P.M.	120.0	118.4	77.5
			3.27 P.M.	110.8	109.0	103.6
			3.56 P.M.	119.0	109.5	117.6
7/14/27	2.08½ P.M.	2.12½ P.M.	2.18 P.M.	125.0	124.4	67.0
			2.24 P.M.	118.7	114.1	111.8
			2.30 P.M.	116.6	113.0	120.2

\* See footnote to table 2.

**TABLE 4**  
 THE EFFECT OF POSTURE UPON THE VOLUME OF CELLS IN BLOOD SIMULTANEOUSLY  
 WITHDRAWN FROM RIGHT ARM, LEFT ARM AND FOOT VEINS

CASE NO.	AVERAGE NO. OF CC. OF CELLS PER 100 CC. OF BLOOD LYING DOWN			STANDING STILL		
	RIGHT ARM VENOUS BLOOD	LEFT ARM VENOUS BLOOD	FOOT VENOUS BLOOD	RIGHT ARM VENOUS BLOOD	LEFT ARM VENOUS BLOOD	FOOT VENOUS BLOOD
1	44.6	44.7	44.5	49.0	49.1	50.6
3	39.4	40.8	40.6	43.5	43.8	45.5
5	49.9	48.1	49.1	51.0	50.5	51.7
Average	44.6	44.5	44.7	47.8	47.8	49.3

TABLE 5

CASE NO.	AVERAGE RED CELL COUNT FOR STANDING STILL POSITION CALCULATED FROM CHANGE			AVERAGE PLASMA PROTEIN FOR STANDING STILL POSITION			AVERAGE PLASMA WATER FOR STANDING STILL POSITION		
	OB-SERVED MLNS. PER CU. MM.	IN TOTAL BLD. VO. MLNS. PER CU. MM.	RATIO OBS./CALC.	OB-SERVED %	CALCULATED FROM PLASMA VOLUME CHANGE %	RATIO OBS./CALC.	OB-SERVED %	CALCULATED FROM PLASMA VOLUME CHANGE %	RATIO OBS./CALC.
1	5.7	5.2	1.096						
2	4.4	4.7	0.937						
3	4.6	4.3	1.070	8.3	8.1	1.023	93.0	92.7	1.002
4A	4.4	4.3	1.000	8.2	7.9	1.038	93.0	93.0	1.000
5	5.1	5.1	1.000	7.8	8.1	0.963	93.4	93.3	1.001
6	4.6	4.4	1.045	7.9	7.2	1.098	93.0	93.2	0.998
Average	4.8	4.7	1.023	8.1	7.8	1.030	93.1	93.1	1.000

TABLE 6

CASE NO.	CC. OF CELLS PER 100 CC. OF BLOOD		TOTAL PLASMA VOLUME (cc.) (BY DYE METHOD)			CALCULATED TOTAL BLOOD VOLUME (cc.)			TOTAL CELL VOLUME (cc.)		
	LYING	STANDING	LYING	STANDING	DIFF.	LYING	STANDING	DIFF.	LYING	STANDING	DIFF.
1	44.6	49.6	3055	2580	-475	5520	5120	-400	2465	2540	+75
2	45.9	48.8	2770	2445	-325	5120	4780	-340	2350	2335	-15
3	40.1	44.2	2140	1900	-240	3575	3405	-170	1430	1505	+75
4A	35.6	38.0	2495	2195	-300	3880	3540	-340	1385	1345	-40
5	47.8	50.9	2505	2160	-345	4800	4400	-400	2295	2240	-55
6	28.1	30.2	2755	2485	-270	3835	3560	-275	1080	1075	-5
Average					-325			-320			+5

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<sup>3</sup> The time varied from 25 to 60 minutes.