JCI The Journal of Clinical Investigation

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J Clin Invest. 1927;3(3):613-629. https://doi.org/10.1172/JCI100104.

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VARIATIONS IN BLOOD FLOW WITH CHANGES IN POSI-TION IN NORMAL AND PATHOLOGIC SUBJECTS¹

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The work reported in this paper was undertaken with the following objects in view: (a) Correlation of the various factors entering into the physiology of circulation under varying conditions; (b) comparison of the circulatory responses of certain pathologic individuals with those obtained in normal subjects.

The work includes simultaneous measurements of blood flow, rate of ventilation, metabolic rate, pulse rate, pulse pressure, cardiac out-put per systole, vital capacity, tension of carbon dioxide in alveolar air, and tension of carbon dioxide in arterial and mixed venous blood with changes of position. Observations have already been made on most, if not all, of these factors individually for the normal subject, but there have been no reports in which simultaneous observations on all of these several factors have been made. The first work on variations in blood flow caused by changes of posture seems to have been done by Lindhard (1) in 1913. No further data on this subject were collected until Field and Bock (2) in 1925 reported a series of observations on blood flow in normal subjects in three positions in which they showed that there was a diminution of blood flow in the sitting or standing posture as compared with the recumbent position.

The variations in ventilation with changes in position were clearly noted by Liljestrand (3) in 1913.

Changes in metabolic rate with shifts in position have already been

¹ The expenses of this research were defrayed in part by the Tutorial Fund of Harvard University.

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noted by Benedict and Benedict (4) in 1924 and more recently by Turner (5).

An excellent report of the changes in blood pressure, pulse pressure and pulse rate is that of Erlanger and Hooker (6). These observers state in their conclusions: "When the standing posture is assumed from the recumbent or the sitting posture, the blood pressures may either rise or fall, the result probably depending largely upon attendant circumstances, such as external temperature, activity of the digestive organs, etc., but the pulse pressure is always diminished and the pulse rate increased." Further work was done on this subject by Sewall (7), who concluded from a study of several hundred cases that there was always a fall in pulse pressure in changing from the recumbent to the standing posture.

The effects of posture on the vital capacity have been known since the time of Hutchinson (8) in the middle of the last century. This observer noted that the vital capacity increased when the subject changed from a recumbent to a sitting or standing position. He also noted that the results obtained in the standing position were greater than those in the sitting posture. Subsequently Bohr (9) in 1907, Christie and Beams (10) in 1922 and 1923 (11) and Rabinowitch (12) in 1923 have confirmed his findings.

The fall in the tension of carbon dioxide in alveolar air has been noted and described by Higgins (13) who found the tension progressively diminished in changing from the recumbent to the sitting and from the sitting to the standing positions, respectively. This, along with a drop in the tension of carbon dioxide in mixed venous blood and an increase in difference between arterial and venous carbon dioxide tension, has for some time been observed by Bock and his co-workers.

Turner (5) has further confirmed these findings.

METHOD

All of the observations in this series were made on subjects who had had no breakfast and who had been lying flat in bed with two small pillows for twenty to thirty minutes. The initial observations were made in all cases with the subject in the recumbent posture,

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usually in the following order: ventilation rate on a calibrated spirometer, circulation experiment proper (i.e., tension of carbon dioxide in alveolar air and tension of carbon dioxide in mixed venous air samples), blood pressure with the arm in the horizontal position, and finally the vital capacity. The subject then sat in a straight backed chair and the previous observations were repeated. Finally the standing posture was assumed and a third series of observations was made. The patient with exophthalmic goitre was so sick that we were forced to allow him to support himself partially by resting his hands on the back of a chair. With this exception, all of the subjects stood quietly without any support.

On one subject (Miss S. P.) we made a fourth set of observations, viz., in the prone position following the standing observations and after a rest period, the experiment was repeated in the recumbent posture. The agreement with the first set of observations was well within the limits of experimental error. Consequently it did not seem to us that the order in which these sets of observations were made was of any material importance.

We have followed essentially the same details in blood flow determinations as those described by Field and Bock in their first paper on this subject. In brief, this consisted in obtaining four alveolar air samples at the end of expiration and four mixed venous air samples simultaneously, the subject being allowed to breathe in and out of the bag (which contained approximately 6 per cent of carbon dioxide and 94 per cent of oxygen) for periods of 10 to 15 seconds. Following or preceding this, the rate of ventilation was measured by means of a calibrated spirometer. In a few instances we did not change the air in the bag for each set of observations and in these cases we found the results to agree with those in which the air was changed for each position. However, we feel that the latter method is less open to error.

RESULTS OF EXPERIMENTS

Tables 1 and 2 may be considered together, as the latter summarizes the important data of the former. The striking finding is the lack of agreement between the metabolic rate and the blood flow, the former showing an increase in every instance but one, the latter a decrease in all but two with the assumption of the sitting or standing

Vital capacity	·93	3,3753,375	3,450	5,200	5,475	5,600	4,125	4,750	4,925	4,150	4,475	4,600	2.525	2,700	2,700
Pulse pres-	mm.	31 24	13	31	20	10	37	50	23	32	28	18	30	20	11
Pulse		61 70	88	58	62	88	70	67	80	63	57	74	65	80	98
Coefficient of utilization		12.2 17.4	21.8	15.5	24.4	28.6	20.4	24.1	31.4	14.8	20.5	34.0	22.4	29.9	40.5
Output pet systole	.93	143 96	67	121	4 8	56	76	105	20	121	109	54	8	58	36
Os per minute	.93	223 231	247	212	267	282	273	335	344	241	271	292	234	253	262
Ventilation per minute	liters	5.48 5.44	7.18	5.05	6.10	7.43	6.82	8.36	9.26	5.00	6.26	7.40	9.20	8.80	10.20
Blood flow per minute	liters	8.92 6.48	5.54	6.74	5.36	4.81	6.80	7.06	5.59	7.64	6.19	4.01	5.82	4.64	3.55
Os capacity	vol- umes per cent	21.54		21.52			20.76			22.52			19.19		
*	mm.	5.14 6.09	7.54	6.01	8.16	9.44	8.55	9.15	11.70	6.00	7.92	11.77	9.50	10.29	12.75
moisnot suons noisnot sOO		45.84 44.85	42.30	46.94	47.44	42.13	47.83	47.18	45.08	46.70	46.40	42.05	36.00	34.28	34.23
Alveolar COs tension		40.70 38.76	34.76	40.93	39.27	32.69	39.28	38.02	33.38	40.70	38.48	30.28	26.51	23.99	21.48
R.Q.		0.848 0.762	0.788	0.786	0.704	0.768	0.896	0.850	0.887	0.783	0.804	0.795	1.180	1.035	0.993
CO2 per min- ute		189 176	194	167	188	216	245	285	307	189	218	232	281	262	260
noitieoA		Lying Sitting	Standing	Lying	Sitting	Standing	Lying	Sitting	Standing	Lying	Sitting	Standing	Lving	Sitting	Standing
Subject, age, weight and height		Mr. J. S. L. 29 years	62 kgm., 169 cm.	Mr. R. E.	26 years	69.9 kgm., 176 cm.	Mr. S. D. B.	27 years	85.5 kgm., 181 cm.	Mr. S. A. O.	27 years	77 kgm., 172.5 cm.	Miss V. I. P.	20 years	64.5 kgm., 170 cm.
Experiment number		I		Π			Η			IV			Ν		

TABLE 1 Blood flow ex**feriments on normal subjects**

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11	Miss S. P. 21 years 56 kgm., 163.5 cm.	Lying Sitting Standing	138 166 173	0.742 0.699 0.884	36.50 37.60 32.89	43.42 44.12 41.90	6.92 6.52 9.01	8.05	4.30 5.53 4.06	5.38 6.68 7.12	186 237 196	56 67 41	25.2 25.0 28.1	77 82 100	29 32 15	2,400 2,675 2,750
	- 	Lying	152	0.810	33.90	42.43	8.53		3.79	6.15	188	54	28.8	70	30	2,350
ΙΙΛ	Miss H. N. L.	Lying	212	0.905	37.60	43.41	5.82	9.43	8.00	5.54	234	8	15.9	81	34	3,600
	23 years	Sitting	193	0.752	37.33	44.83	7.50		5.64	5.42	257	8:	24.7	8	8	4,150
	66.5 kgm., 173.5 cm.	Standing	189	0.772	31.27	41.37	10.10		3.88	5.54	245	42	34.2	92	18	4,250
VIII	Mr. L. M. H.	Lying	227	0.992	39.43	47.68	8.252	1.22	6.43	6.38	246	102	17.7	63	27	5,200
	29 years	Sitting	227	0.772	37.46	45.63	8.17		6.17	7.20	294	101	23.7	61	52	5,450
	80 kgm., 185 cm.	Standing	192	0.808	35.36	42.98	7.63		5.39	6.43	238	62	21.9	87	12	5,575
X	Mr. C. D.	T.ving	185	0 866	43 15	40 12	5 97 2	0 22	8 12	5 08	211	176	13 7	46	27	5.000
	38 years	Sitting	229	0.891	38.56	47.00	8.43		6.21	6.84	257	135	21.5	46	28	5,250
	172 cm.	Standing	216	0.854	35.85	45.57	9.72		4.85	7.40	253	87	27.1	56	17	5,400
×	Mr. T. D. J.	Lying	162	0.871	39.27	46.77	7.492	2.64	5.23	5.21	186	75	17.4	70	32	2,875
	27 years	Sitting	170	0.814	38.56	47.73	9.17		4.27	6.85	209	56	22.7	76	30	2,975
	55 kgm., 161 cm.	Standing	171	0.802	33.91	46.16	12.25		3.02	7.39	213	34	32.9	80	23	3100

 $*\Delta = \text{difference between alveolar and mixed venous carbon dioxide tensions.}$

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		Perc	entile var	iation fro	m supine	position	in norm	al subject	ts				,
Experi- ment number	Subject	Position	CO2 expired	Alveolar CO ₂ tension	Mixed venous CO ₂ tension	*2	Blood flow	Ventila- tion	Meta- bolic rate	Pulse rate	P ulse pressure	Vital capacity	Output per systole
н	Mr. J. S. L.	Sitting Standing	-6.9 +2.6	-4.8 -14.6	-2.2	+18.7 +47.2	-27.4 -37.9	-0.7 + 31.0	+3.6	+14.8 +44.3	-22.6	+3.7 +2.2	-32.9 -53.1
Η	Mr. R. E.	Sitting Standing	+12.6 +29.3	-4.1 -20.1	+1.1 -10.2	+35.8 +57.1	-20.5 -28.6	+20.8 +47.1	+25.3 +32.4	+6.9 +51.8	-35.5 -67.8	+5.3 +7.7	-30.6 -53.7
III	Mr.'S. D. B.	Sitting Standing	+16.3 +25.3	-3.2	-1.4 -57.5	+7.0 +36.8	+3.8 -17.8	+22.6 +35.8	+22.7 +26.0	-4.3 +14.3	-21.6 -37.9	+15.2 +19.4	+8.3 -27.8
N	Mr. S. A. O.	Sitting Standing	+15.3 +22.7	-5.5 -22.1	-0.6	+32.0 +96.2	-17.0 -47.5	+25.2 +48.0	+12.4 +21.2	-9.5 +17.5	-12.5 -43.8	+7.8 +10.8	-9.9 -55.4
>	Miss V.J.P.	Sitting Standing	-6.8 -7.5	-9.5 -19.0	-4.8	+8.3 +34.2	-20.3 -39.0	-4.4 +10.9	+8.1 +12.0	+23.1 +50.8	-33.3 -63.4	+6.9 +6.9	-35.6 -60.0
IV	Miss S. P.	Sitting Standing	+20.3 +25.4	+3.0 -9.9	+1.6 -3.5	-5.8 +30.2	+28.6 -5.6	+24.2 +32.4	+27.4 +5.4	+6.5 +29.9	+10.3 -48.3	+11.5 +14.6	+19.6 -26.8
ПЛ	Miss H. M. L.	Sitting Standing	-9.0 -10.9	-0.7 -16.9	+3.3 -4.7	+28.9 +73.6	-29.5 -51.5	-2.2 0.0	+9.9 +4.7	-16.1 +13.6	-11.8 -47.1	+15.3 +18.1	-16.2 -57.6
IIIA	Mr. L. M. H.	Sitting Standing	0.0 - 15.4	-5.0 -10.3	-4.3	-1.0 -7.5	-4.0 -16.2	+12.9 +0.8	+19.5 -3.3	-3.2 + 38.1	-18.5 -55.6	+4.8 +7.2	-1.0 -39.2

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TABLE 2

r +5.0 -23.3	8 +3.5 -25.3	8 +7.9 -14.7
+8.0 -50.6	+7.8 -54.7	1 +10.3 -47.9
+3.7	-6.3	- 14.8
-37.1	-28.1	- 48.7
0.0	+8.6	+2.7
+21.8	+27.2	+30.9
+21.8	+12.4	+16.3
+19.9	+14.5	+14.3
+34.7	+31.5	+16.4
+45.7	+41.8	+29.4
-23.5	-18.4	-12.8
-40.3	-42.3	-32.7
+41.2	+22.4	+18.8
+62.8	+63.6	+49.4
-4.3	+2.1	-0.95
-7.2	-1.3	-11.6
-10.6	-1.8	-4.1
-16.9	-13.6	-15.8
+23.8	+4.9	+7.1
+16.8	+5.6	+9.4
Sitting Standing	Sitting Standing	
Mr . C. D.	Mr. T. D. J.	ttinganding
X	×	Av. Si Av. St

 $\Delta = difference$ between alveolar and mixed venous carbon dioxide tensions.

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Blood flow experiments on subjects with pathologic conditions

Vital capacity	. 22	3,150 3,350	3,775 3,750 3,500	3,625 3,925 3,575	4,850 5,100 5,300	2,500 2,975 3,000	2,400 2,525
Pulse pr e s-	.mm.	40 10	30 50 30	40 43 33	40 26 16	31 33 40	66 41
Pulse rate		74 110	80 88 138	80 84 108	60 78 110	70 70 81	110 127
Coefficient of utilization		22.8 37.2		8.0 13.9 21.8	30.7 27.3 26.3	24.9 30.5 34.8	25.4 38.7
Systole Systole	<i>cc.</i>	70 46	93 61 37	177 99 60	78 91 53	71 73 47	96 98
otunim 19q 2 O	. 99	241 382	208 261 266	186 192 235	255 343 274	200 254 207	464 657
Ventilation per minute	lilers	6.58 9.46	6.18 7.47 8.12	7.30 9.48 9.07	7.94 13.83 14.86	4.82 8.80 6.57	14.92 22.90
Blood flow per minute	liters	5.17 5.09	7.47 5.39 5.09	14.16 8.32 6.49	4.65 7.06 5.84	4.94 5.12 3.82	10.55 12.44
O2 capacity	vol- umes per cent	21.27		17.50	18.78	17.10	18.21
*	mm.	7.51	5.90 8.69 9.38	3.14 5.36 6.87	9.66 9.10 9.47	7.02 9.84 10.41	8.27 10.67
zuonsy bsizion CO2 tension	mm.	46.26 42.42	45.71 44.65 42.02	38.35 40.34 42.64	38.36 34.50 33.05	42.45 42.88 43.40	38.87 40.29
Alveolar CO ² tension	.um	38.75 32.10	39.81 35.90 32.64	35.20 34.98 35.77	28.70 25.40 23.58	35.44 33.04 32.99	30.60
<i>к</i> .و.		0.715 0.654	0.914 0.840 0.848	0.992 1.050 0.880	0.888 1.004 1.125	0.804 0.941 0.876	0.916 0.788
CO2 per min- ute	.99	170	190 219 226	187 202 207	226 345 308	161 239 181	518
Position		Lying Standing	Lying Sitting Standing	Lying Sitting Standing	Lying Sitting Standing	Lying Sitting Standing	Lying Standing
Diagnosis		Convalescence	Convalescence; mi tral stenosis; well compensated	Convalescence	Convalescence	Mitral stenosis; aor- tic regurgitation; well compensated	Toxic goiter
Subject, age, weight and height		Mr. S. I. J. 64 years	Mr. J. J. F. 21 years 61 kgm., 175 cm.	Mr. J. McM. 68 years 55 kgm., 166 cm.	Mr. C. F. W. W. 47 years 87 kgm., 192 cm.	Miss. M. J. J. 21 years 58 kgm., 163 cm.	Mr. J. C. V. 47 years 65.3 kgm., 172 cm.
Experiment number		X	ПХ	IIIX	XIX	XV	IVX

0 13 2,450 0 16 2,575	4 36 2,400 4 40 2,675 4 40 2,675 4 36 2,500	2 26 2,400 8 18 2,425 0 13 2,350
23.5 5 21.6 71 21.5 80	28.6 6 34.5 6 52.3 7	300
65 59	56 67 43	49 52 52
145	142	179
166	208	223
167	236	227
4.02	7.12	4.36
5.12	10.57	5.73
5.26	11.10	6.19
3.75	3.55	3.04
4.68	4.31	3.95
4.73	3.21	4.03
17.27	14.82	
7.16	8.88	9.46
6.74	9.07	8.40
6.48	9.54	8.75
37.92	32.36	43.30
44.00	29.34	42.45
40.89	27.63	42.05
0.76	3.48 0.27 8.09	3.84 4.05
.892 3	.2402	. 762 3
.879 3	.1252	. 706 3
.843 3	.9531	. 730 3
129 0	177 1	136 0
146 0	235 1	156 0
141 0	225 0	166 0
Lying	Lying	Lying
Sitting	Sitting	Sitting
Standing	Standing	Standing
		-
Myxedema	Myxedema	Myxedema
Mrs. E. M. D.	Mrs. J. W.	Mrs. M. V. L.
52 years	46 years	47 years
73.5 kgm., 155 cm.	51.3 kgm., 152 cm.	80 kgm., 154 cm.
IIVX	ШЛХ	XIX

 $*\Delta = difference between alveolar and mixed venous carbon dioxide tensions.$

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	Output per systole	-34.3	34.4 60.2	-44.1 -66.1	+16.7 -32.1	-20.6 -48.2	+2.8 -33.8	+2.1
	Vital capacity	+6.4	-0.7 -7.3	+8.3 -1.4	+5.2 +9.3	+4.3 +1.8	+19.0 +20.0	+5.2
	Pulse	-75.0	-16.7 -50.0	+7.5 -17.5	-35.0	-14.7 -50.6	+6.5 +29.0	-37.9
	Pulse rate	+48.7	+10.0 +72.5	+5.0 +35.0	+30.0 +83.3	+15.0 +59.9	0.0 +15.7	+15.4
	Meta- bolic rate	+17.0	+25.5 +27.9	+3.2 +26.3	+34.5 +7.5	+21.1+19.6	+27.0 +3.5	+41.6
ects	Ventila- tion	+43.8	+20.9	+29.9 +24.3	+74.2 +87.2	+41.7 +46.7	+82.6 +36.3	+53.5
gic subj	Blood flow	-1.5	-27.8 -31.9	-41.2 -54.2	+51.8 +25.6	-5.7 -15.5	+3.6 -22.7	+17.9
ı patholo	*⊽	+37.4	+47.3 +59.0	+70.7 +118.7	-5.8	+37.4 +53.3	+40.2 +48.3	+29.0
sition i	Mixed venous CO ₃ tension	-8.3	-2.3 -8.1	+5.2 +11.2	-10.1 -13.8	-2.6 -4.8	+1.0+2.2	+3.7
tpine po	Alveolar CO ₂ tension	-17.2	-9.8 18.0	-0.6 +1.6	-11.5 -17.8	-7.3 -12.9	-6.9 -6.9	-3.2
from sı	CO ₂ ex- pired	+47.1	+15.3 +19.0	+8.0	+52.7 +36.3	+25.3 +28.3	+48.4 +12.4	+21.9
tile variation	Position	Standing	Sitting Standing	Sitting Standing	Sitting Standing		Sitting Standing	Standing
Percent	Diagnosis	Convalescence	Convalescence; mitral stenosis; well compen- sated	Convalescence	Convalescence		Mitral stenosis; aoritic regurgita- tion: well com- pensated	Toxic goiter
	Subject	Mr. S. I. J.	Mr. J. J. F.	Mr. J. McM.	Mr. C. F. W. W.	tting	Mrs. M. J. J.	Mr. J. C. V.
	Experi- ment number	X	IIX	ШХ	XIV	Av. Si Av. St	xv	IVX

TABLE 4

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плх	Mrs. E. M. D.	Myxedema	Sitting Standing	+13.2 +9.3	+21.2 + 11.9	+16.0 +7.8	-5.9	+24.8 +26.1	+27.4 +30.9	+14.5 +15.2	+20.7 +37.9	-53.6 -42.9	+12.6 +18.4	+3.1 -9.2
ТПЛХ	Mrs. J. W.	Myxedema	Sitting Standing	+32.3 +27.1	-13.7	-9.3 -14.6	+2.1	+21.4	+46.5 +55.9	+46.5 +66.2	0.0 +15.6	+11.1 0.0	+11.5 +4.2	+19.7 -23.2
XIX	Mrs. M. V. L.	Myxedema	Sitting Standing	+14.7 +22.1	+0.6 -1.6	-2.0 -2.9	-11.2 -7.5	+29.9	+31.4 +42.0	+24.6 +26.8	+9.7 +12.9	-30.8 -50.0	+1.0 -2.1	+20.4 +6.1
Av. Si Av. St	tting			+20.2 +19.5	+2.7 -4.2	+1.6 -3.2	-5.0 -3.2	+25.4 +16.3	+35.8 +42.9	+28.5 +36.1	+10.1 +22.1	-24.4 -31.0	+8.4 +6.8	+14.4 -8.8

 $*\Delta = difference$ between alveolar and mixed venous carbon dioxide tensions.

postures. These results are so consistent that we feel they must be true.

The only explanation which we have to offer for this divergence between metabolic rate and blood flow in different postures is that the effect of gravity, slowing the circulation rate, may be greater than the tendency for an elevated metabolism to increase it. In exercise this is not the case, since the circulation rate readily keeps pace with the increase in metabolism because the effect of gravity is eliminated as a result of muscular action.

Another point to be mentioned is the presence of hyperventilation in untrained subjects. This is best demonstrated in the case of Miss V. J. P., by the high ventilation rate, the high respiratory quotients (over 1.00 in lying and sitting positions) and the very low tension of carbon dioxide in alveolar air in the presence of a normal pulse rate. Hyperventilation does not seem to have affected the blood flow in this case, as the figures are about those which we should have expected in an individual of her size. Hyperventilation is a familiar phenomenon in untrained subjects. DuBois (14) speaks of it at some length in his book, "Basal Metabolism in Health and Disease," and it has also been observed by Peters and Barr (15).

Pearce's (16) explanation of hyperventilation as a compensatory mechanism in conditions in which the blood flow is unable to keep pace with the metabolism does not seem to apply in these cases.

Tables 3 and 4 deal entirely with pathologic subjects, of whom there are four groups—convalescent, cardiac, hyperthyroid and myxedematous patients.

The group of convalescent patients were all post-operative and had been out of bed for only a few days. Two of these had been in bed seventeen days, one twenty-three days, and another eight days. It will be noted that there was a very great rise in ventilation rate (nearly fifty per cent) on changing from lying to sitting or standing posture. However, it should be recalled that these subjects were not trained and there was necessarily a definite element of excitement present. This manifested itself particularly in hyperventilation which was present in two of the cases, being greatest in C. F. W. W. The pulse rate, also, was affected to a much greater extent by posture than in normal individuals. This is to be expected in subjects who were in the unstable condition of convalescence.

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The changes in vital capacity were not so great as in normal subjects. It is of interest that the blood flow in this group diminished only about one-half as much as in our normal subjects with the same postural changes. In other words, a reduction in blood flow on sitting or standing seems to be a characteristic of the normal healthy individual more particularly than of the unstable convalescent. If future work confirms this finding, the changes found in normal subjects suggest a possible compensatory mechanism not yet reestablished in the convalescent subject. It might be mentioned here that certain athletes show the same changes in blood flow as non-athletic subjects do. This was demonstrated very well by C. D., a winner in eight out of eighteen Marathon races. He showed a

Average coefficient of uti	lization of ox	ygen	
Diagnosis	Lying	Sitting	Standing
Normal	17.5	23.5	31.0
Convalescence	20.5	20.5	28.5
Rheumatic heart disease	25.0	30.5	35.0
Toxic goiter	25.5		38.5
Myxedema	26.0	28.0	37.0

TABLE 5

diminution of approximately twenty-five per cent in blood flow in the sitting and forty per cent in the standing position.

The low tension of carbon dioxide in the alveolar air of C. F. W. W. is very striking. This individual was hyperventilating to an unusual degree in the absence of any abnormal physical findings.

The one subject with rheumatic heart disease with mitral stenosis and aortic regurgitation without decompensation was remarkable chiefly in two respects, viz: (a) The pulse pressure was increased rather than diminished in the sitting and standing postures, being one-third greater in the latter position. (b) The vital capacity showed a greater relative increase than in any other subject studied. It should be stated, however, that two of our normal subjects showed increases closely approaching these values.

The significance of the results obtained in the case just mentioned is not clear at present. Christie and Beams (11) have reported ob-



servations on vital capacity as related to posture in patients with diminished vital capacity due to different causes. While it is true that they found a greater increase with change of posture in such patients with orthopnea, yet they found no increase above normal in such patients without orthopnea. Our subjects showed no diminution in vital capacity and no orthopnea.

The only other subject with a cardiac lesion in this series is J. J. F. who had mitral stenosis without signs of heart failure. He did not present findings similar to the above.

This series includes only one subject with exophthalmic goiter. He showed in the standing posture an increase in blood flow which was not nearly commensurate with the increase in metabolism. (The subject was so toxic that it is difficult to rely on the findings in his case.)

The short series of cases with myxedema presented the greatest variations from the normal. It is significant that the blood flow instead of being diminished on changing from the lying to the sitting or standing positions was increased. Although it is true that here we were dealing with very much smaller values as regards blood flow than in the normal subjects, yet the percentile differences were so consistently increased as to seem of some importance. The tensions of carbon dioxide in alveolar air were low. The unusually low values in J. W. were, no doubt, due to hyperventilation. The explanation of the other low values is difficult.

Table 5 shows the average coefficient of utilization of oxygen in the three positions in the various types of subjects studied. It will be seen that there was a definite increase in the coefficient of utilization of oxygen in changes from the lying to the sitting and standing postures. The subjects with heart lesions, exophthalmic goiter and myxedema presented the highest values.

In figure 1 are shown graphically what happens to the various factors discussed as a result of posture, (a) in the average normal, and (b) in subjects with myxedema. If such a short series can be taken as presenting trustworthy evidence, there is seen to be a very striking difference in the subjects with myxedema.

VARIATIONS IN BLOOD FLOW WITH POSITION

CONCLUSIONS

1. In normal subjects the blood flow, pulse pressure, and tension of carbon dioxide in alveolar and mixed venous air samples *diminish* as one changes from the lying to the sitting or standing postures.

2. In normal subjects the ventilation, metabolic rate, pulse rate, vital capacity and difference in tension between carbon dioxide in alveolar and mixed venous air samples *increase* from the lying to sitting or standing positions.

3. The subjects showing pathologic conditions have been too few in number to admit of definite, reliable conclusions but, at least, they do indicate that responses different from the normal may be obtained in some instances.

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