VARIATIONS IN BLOOD FLOW WITH CHANGES IN POSITION IN NORMAL AND PATHOLOGIC SUBJECTS[1]

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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

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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,

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

TABLE 1

Blood flow experiments on normal subjects

Experiment number	Subject, age, weight and height	Position	CO_2 per minute	R.Q.	Alveolar CO_2 tension	Mixed venous CO_2 tension	Δ*	O_2 capacity	Blood flow per minute	Ventilation per minute	O_2 per minute	Output pet systole	Coefficient of utilization	Pulse	Pulse pressure	Vital capacity
			cc.		*mm.*	*mm.*	*mm.*	*volumes per cent*	*liters*	*liters*	*cc.*	*cc.*			*mm.*	*cc.*
I	Mr. J. S. L.	Lying	189	0.848	40.70	45.84	5.14	21.54	8.92	5.48	223	143	12.2	61	31	3,375
	29 years	Sitting	176	0.762	38.76	44.85	6.09		6.48	5.44	231	96	17.4	70	24	3,500
	62 kgm., 169 cm.	Standing	194	0.788	34.76	42.30	7.54		5.54	7.18	247	67	21.8	88	13	3,450
II	Mr. R. E.	Lying	167	0.786	40.93	46.94	6.01	21.52	6.74	5.05	212	121	15.5	58	31	5,200
	26 years	Sitting	188	0.704	39.27	47.44	8.16		5.36	6.10	267	84	24.4	62	20	5,475
	69.9 kgm., 176 cm.	Standing	216	0.768	32.69	42.13	9.44		4.81	7.43	282	56	28.6	88	10	5,600
III	Mr. S. D. B.	Lying	245	0.896	39.28	47.83	8.55	20.76	6.80	6.82	273	97	20.4	70	37	4,125
	27 years	Sitting	285	0.850	38.02	47.18	9.15		7.06	8.36	335	105	24.1	67	29	4,750
	85.5 kgm., 181 cm.	Standing	307	0.887	33.38	45.08	11.70		5.59	9.26	344	70	31.4	80	23	4,925
IV	Mr. S. A. O.	Lying	189	0.783	40.70	46.70	6.00	22.52	7.64	5.00	241	121	14.8	63	32	4,150
	27 years	Sitting	218	0.804	38.48	46.40	7.92		6.19	6.26	271	109	20.5	57	28	4,475
	77 kgm., 172.5 cm.	Standing	232	0.795	30.28	42.05	11.77		4.01	7.40	292	54	34.0	74	18	4,600
V	Miss V. J. P.	Lying	281	1.180	26.51	36.00	9.50	19.19	5.82	9.20	234	90	22.4	65	30	2,525
	20 years	Sitting	262	1.035	23.99	34.28	10.29		4.64	8.80	253	58	29.9	80	20	2,700
	64.5 kgm., 170 cm.	Standing	260	0.993	21.48	34.23	12.75		3.55	10.20	262	36	40.5	98	11	2,700

VI	Miss S. P.	Lying	138	0.742	36.50	43.42	6.92	18.05	4.30	5.38	186	56	25.2	77	29	2,400
	21 years	Sitting	166	0.699	37.60	44.12	6.52		5.53	6.68	237	67	25.0	82	32	2,675
	56 kgm., 163.5 cm.	Standing	173	0.884	32.89	41.90	9.01		4.06	7.12	196	41	28.1	100	15	2,750
		Lying	152	0.810	33.90	42.43	8.53		3.79	6.15	188	54	28.8	70	30	2,350
VII	Miss H. N. L.	Lying	212	0.905	37.60	43.41	5.82	19.43	8.00	5.54	234	99	15.9	81	34	3,600
	23 years	Sitting	193	0.752	37.33	44.83	7.50		5.64	5.42	257	83	24.7	68	30	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	8.25	21.22	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	22	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
IX	Mr. C. D.	Lying	185	0.866	43.15	49.12	5.97	20.22	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
X	Mr. T. D. J.	Lying	162	0.871	39.27	46.77	7.49	22.64	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	89	23	3100

*Δ = difference between alveolar and mixed venous carbon dioxide tensions.

TABLE 2

Percentile variation from supine position in normal subjects

Experiment number	Subject	Position	CO_2 expired	Alveolar CO_2 tension	Mixed venous CO_2 tension	Δ*	Blood flow	Ventilation	Metabolic rate	Pulse rate	Pulse pressure	Vital capacity	Output per systole
I	Mr. J. S. L.	Sitting	−6.9	−4.8	−2.2	+18.7	−27.4	−0.7	+3.6	+14.8	−22.6	+3.7	−32.9
		Standing	+2.6	−14.6	−7.7	+47.2	−37.9	+31.0	+10.8	+44.3	−58.1	+2.2	−53.1
II	Mr. R. E.	Sitting	+12.6	−4.1	+1.1	+35.8	−20.5	+20.8	+25.3	+6.9	−35.5	+5.3	−30.6
		Standing	+29.3	−20.1	−10.2	+57.1	−28.6	+47.1	+32.4	+51.8	−67.8	+7.7	−53.7
III	Mr. S. D. B.	Sitting	+16.3	−3.2	−1.4	+7.0	+3.8	+22.6	+22.7	−4.3	−21.6	+15.2	+8.3
		Standing	+25.3	−15.0	−57.5	+36.8	−17.8	+35.8	+26.0	+14.3	−37.9	+19.4	−27.8
IV	Mr. S. A. O.	Sitting	+15.3	−5.5	−0.6	+32.0	−17.0	+25.2	+12.4	−9.5	−12.5	+7.8	−9.9
		Standing	+22.7	−22.1	−10.0	+96.2	−47.5	+48.0	+21.2	+17.5	−43.8	+10.8	−55.4
V	Miss V.J.P.	Sitting	−6.8	−9.5	−4.8	+8.3	−20.3	−4.4	+8.1	+23.1	−33.3	+6.9	−35.6
		Standing	−7.5	−19.0	−4.9	+34.2	−39.0	+10.9	+12.0	+50.8	−63.4	+6.9	−60.0
VI	Miss S. P.	Sitting	+20.3	+3.0	+1.6	−5.8	+28.6	+24.2	+27.4	+6.5	+10.3	+11.5	+19.6
		Standing	+25.4	−9.9	−3.5	+30.2	−5.6	+32.4	+5.4	+29.9	−48.3	+14.6	−26.8
VII	Miss H. M. L.	Sitting	−9.0	−0.7	+3.3	+28.9	−29.5	−2.2	+9.9	−16.1	−11.8	+15.3	−16.2
		Standing	−10.9	−16.9	−4.7	+73.6	−51.5	0.0	+4.7	+13.6	−47.1	+18.1	−57.6
VIII	Mr. L. M. H.	Sitting	0.0	−5.0	−4.3	−1.0	−4.0	+12.9	+19.5	−3.2	−18.5	+4.8	−1.0
		Standing	−15.4	−10.3	−9.9	−7.5	−16.2	+0.8	−3.3	+38.1	−55.6	+7.2	−39.2

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

* Δ = difference between alveolar and mixed venous carbon dioxide tensions.

TABLE 3

Blood flow experiments on subjects with pathologic conditions

Experiment number	Subject, age, weight and height	Diagnosis	Position	CO_2 per minute	R.Q.	Alveolar CO_2 tension	Mixed venous CO_2 tension	Δ*	O_2 capacity	Blood flow per minute	Ventilation per minute	O_2 per minute	Output per systole	Coefficient of utilization	Pulse rate	Pulse pressure	Vital capacity
				cc.		*mm.*	*mm.*	*mm.*	*volumes per cent*	*liters*	*liters*	*cc.*	*cc.*			*mm.*	*cc.*
XI	Mr. S. I. J.	Convalescence	Lying	170	0.715	38.75	46.26	7.51	21.27	5.17	6.58	241	70	22.8	74	40	3,150
	64 years		Standing	250	0.654	32.10	42.42	10.32		5.09	9.46	382	46	37.2	110	10	3,350
XII	Mr. J. J. F.	Convalescence; mi	Lying	190	0.914	39.81	45.71	5.90		7.47	6.18	208	93		80	60	3,775
	21 years	tral stenosis; well	Sitting	219	0.840	35.90	44.65	8.69		5.39	7.47	261	61		88	50	3,750
	61 kgm., 175 cm.	compensated	Standing	226	0.848	32.64	42.02	9.38		5.09	8.12	266	37		138	30	3,500
XIII	Mr. J. McM.	Convalescence	Lying	187	0.992	35.20	38.35	3.14	17.50	14.16	7.30	186	177	8.0	80	40	3,625
	68 years		Sitting	202	1.050	34.98	40.34	5.36		8.32	9.48	192	99	13.9	84	43	3,925
	55 kgm., 166 cm.		Standing	207	0.880	35.77	42.64	6.87		6.49	9.07	235	60	21.8	108	33	3,575
XIV	Mr. C. F. W. W.	Convalescence	Lying	226	0.888	28.70	38.36	9.66	18.78	4.65	7.94	255	78	30.7	60	40	4,850
	47 years		Sitting	345	1.004	25.40	34.50	9.10		7.06	13.83	343	91	27.3	78	26	5,100
	87 kgm., 192 cm.		Standing	308	1.125	23.58	33.05	9.47		5.84	14.86	274	53	26.3	110	16	5,300
XV	Miss. M. J. J.	Mitral stenosis; aor-	Lying	161	0.804	35.44	42.45	7.02	17.10	4.94	4.82	200	71	24.9	70	31	2,500
	21 years	tic regurgitation;	Sitting	239	0.941	33.04	42.88	9.84		5.12	8.80	254	73	30.5	70	33	2,975
	58 kgm., 163 cm.	well compensated	Standing	181	0.876	32.99	43.40	10.41		3.82	6.57	207	47	34.8	81	40	3,000
XVI	Mr. J. C. V.	Toxic goiter	Lying	425	0.916	30.60	38.87	8.27	18.21	10.55	14.92	464	96	25.4	110	66	2,400
	47 years		Standing	518	0.788	29.62	40.29	10.67		12.44	22.90	657	98	38.7	127	41	2,525
	65.3 kgm., 172 cm.																

XVII	Mrs. E. M. D.	Myxedema	Lying	129	0.892	30.76	37.92	7.16	17.27	3.75	4.02	145	65	23.5	58	28	2,175
	52 years		Sitting	146	0.879	37.26	44.00	6.74		4.68	5.12	166	67	21.6	70	13	2,450
	73.5 kgm., 155 cm.		Standing	141	0.843	34.42	40.89	6.48		4.73	5.26	167	59	21.5	80	16	2,575
XVIII	Mrs. J. W.	Myxedema	Lying	177	1.240	23.48	32.36	8.88	14.82	3.55	7.12	142	56	28.6	64	36	2,400
	46 years		Sitting	235	1.125	20.27	29.34	9.07		4.31	10.57	208	67	34.5	64	40	2,675
	51.3 kgm., 152 cm.		Standing	225	0.953	18.09	27.63	9.54		3.21	11.10	236	43	52.3	74	36	2,500
XIX	Mrs. M. V. L.	Myxedema	Lying	136	0.762	33.84	43.30	9.46		3.04	4.36	179	49		62	26	2,400
	47 years		Sitting	156	0.706	34.05	42.45	8.40		3.95	5.73	223	59		68	18	2,425
	80 kgm., 154 cm.		Standing	166	0.730	33.30	42.05	8.75		4.03	6.19	227	52		70	13	2,350

*Δ = difference between alveolar and mixed venous carbon dioxide tensions.

TABLE 4

Percentile variation from supine position in pathologic subjects

Experiment number	Subject	Diagnosis	Position	CO_2 expired	Alveolar CO_2 tension	Mixed venous CO_2 tension	Δ*	Blood flow	Ventilation	Metabolic rate	Pulse rate	Pulse pressure	Vital capacity	Output per systole
XI	Mr. S. I. J.	Convalescence	Standing	+47.1	−17.2	−8.3	+37.4	−1.5	+43.8	+17.0	+48.7	−75.0	+6.4	−34.3
XII	Mr. J. J. F.	Convalescence; mitral stenosis; well compensated	Sitting	+15.3	−9.8	−2.3	+47.3	−27.8	+20.9	+25.5	+10.0	−16.7	−0.7	−34.4
			Standing	+19.0	−18.0	−8.1	+59.0	−31.9	+31.4	+27.9	+72.5	−50.0	−7.3	−60.2
XIII	Mr. J. McM.	Convalescence	Sitting	+8.0	−0.6	+5.2	+70.7	−41.2	+29.9	+3.2	+5.0	+7.5	+8.3	−44.1
			Standing	+10.7	+1.6	+11.2	+118.7	−54.2	+24.3	+26.3	+35.0	−17.5	−1.4	−66.1
XIV	Mr. C. F. W. W.	Convalescence	Sitting	+52.7	−11.5	−10.1	−5.8	+51.8	+74.2	+34.5	+30.0	−35.0	+5.2	+16.7
			Standing	+36.3	−17.8	−13.8	−2.0	+25.6	+87.2	+7.5	+83.3	−60.0	+9.3	−32.1
Av. Sitting				+25.3	−7.3	−2.6	+37.4	−5.7	+41.7	+21.1	+15.0	−14.7	+4.3	−20.6
Av. Standing				+28.3	−12.9	−4.8	+53.3	−15.5	+46.7	+19.6	+59.9	−50.6	+1.8	−48.2
XV	Mrs. M. J. J.	Mitral stenosis; aoritic regurgitation: well compensated	Sitting	+48.4	−6.8	+1.0	+40.2	+3.6	+82.6	+27.0	0.0	+6.5	+19.0	+2.8
			Standing	+12.4	−6.9	+2.2	+48.3	−22.7	+36.3	+3.5	+15.7	+29.0	+20.0	−33.8
XVI	Mr. J. C. V.	Toxic goiter	Standing	+21.9	−3.2	+3.7	+29.0	+17.9	+53.5	+41.6	+15.4	−37.9	+5.2	+2.1

XVII	Mrs. E. M. D.	Myxedema	Sitting	+13.2	+21.2	+16.0	−5.9	+24.8	+27.4	+14.5	+20.7	−53.6	+12.6	+3.1
			Standing	+9.3	+11.9	+7.8	−9.5	+26.1	+30.9	+15.2	+37.9	−42.9	+18.4	−9.2
XVIII	Mrs. J. W.	Myxedema	Sitting	+32.3	−13.7	−9.3	+2.1	+21.4	+46.5	+46.5	0.0	+11.1	+11.5	+19.7
			Standing	+27.1	−23.0	−14.6	+7.4	−9.6	+55.9	+66.2	+15.6	0.0	+4.2	−23.2
XIX	Mrs. M. V. L.	Myxedema	Sitting	+14.7	+0.6	−2.0	−11.2	+29.9	+31.4	+24.6	+9.7	−30.8	+1.0	+20.4
			Standing	+22.1	−1.6	−2.9	−7.5	+32.5	+42.0	+26.8	+12.9	−50.0	−2.1	+6.1
Av. Sitting				+20.2	+2.7	+1.6	−5.0	+25.4	+35.8	+28.5	+10.1	−24.4	+8.4	+14.4
Av. Standing				+19.5	−4.2	−3.2	−3.2	+16.3	+42.9	+36.1	+22.1	−31.0	+6.8	−8.8

*Δ = 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.

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 re-established 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

TABLE 5

Average coefficient of utilization of oxygen

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

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-

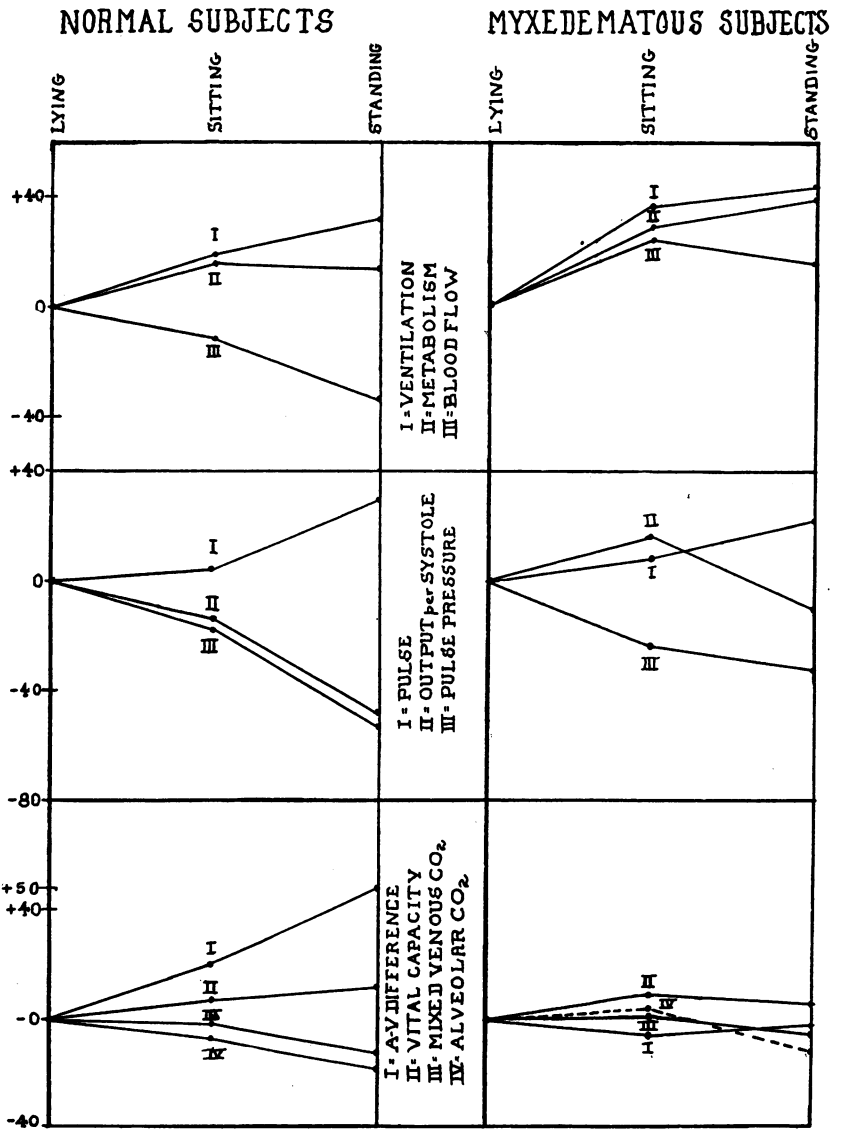
NORMAL SUBJECTS
MYXEDEMATOUS SUBJECTS
LYING
SITTING
STANDING
LYING
SITTING
STANDING
+40
0
-40
+40
0
-40
-80
+50
+40
-0
-40
I
II
III
IV
I=VENTILATION
II=METABOLISM
III=BLOOD FLOW
I=PULSE
II=OUTPUT per SYSTOLE
III=PULSE PRESSURE
I=A-V DIFFERENCE
II=VITAL CAPACITY
III=MIXED VENOUS CO_2
IV=ALVEOLAR CO_2

FIG. 1

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.

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.

BIBLIOGRAPHY

1. Lindhard, J.: Skand. Arch. f. Physiol., 1913, xxx, 395. Effect of Posture on the Output of the Heart.
2. Field, H., and Bock, A. V.: Jour. Clin. Invest., 1925, ii, 67. Orthopnea and the Effect of Posture upon the Rate of Blood Flow.
3. Liljestrand, G., and Wollin, G.: Skand. Arch. f. Physiol., 1913, xxx, 199. Über den Einfluss der Korperstellung auf die Atmung des Menschen.
4. Benedict, F. G., and Benedict, C. G.: Proc. Nat. Acad. Sc., 1924, x, 498. Body Posture and Minor Muscular Movements as Affecting Heat Production.
5. Turner, Abby H.: Thesis, Physiology Dept., Harvard Univ., 1926. Respiratory and Circulatory Test of Physical Fitness in Healthy Young Women.
6. Erlanger, J., and Hooker D. R.: Johns Hopkins Hosp. Rep., 1904, xii, 145. An Experimental Study of Blood Pressure and of Pulse-Pressure in Man.
7. Sewall, H.: Amer. Jour. Med. Sc., 1919, clviii, 786. On the Clinical Significance of Posture Changes in the Blood Pressures, and the Secondary Waves of Arterial Blood Pressure.
8. Hutchinson, J.: Med. Chir. Trans. London, 1846, xxix, 137. On the Capacity of the Lungs and on the Respiratory Functions.
   Hutchinson, J.: Lancet, 1846, 1, 630. On the Capacity of the Lungs and on the Respiratory Movements.
   Hutchinson, J.: Spirometer, the Stethoscope, and Scale Balance; Their Use in Discriminating Diseases of the Chest and Their Values in Life Offices. Churchill, London, 1852.
9. Bohr, C.: Deutsch Arch. f. Klin. Med., 1907, lxxxviii, 385. Die funktionellen Änderungen in der Mittellage und Vitalkapazität der Lungen.
10. Christie, C. D., and Beams, A. J.: Arch. Int. Med., 1922, xxx, 34. The Estimation of Normal Vital Capacity, with Especial Reference to Effect of Posture.

11. Christie, C. D., and Beams, A. J.: Arch. Int. Med., 1923, xxxi, 85. Orthopnea.
12. Rabinowitch, I. M.: Arch. Int. Med., 1923, xxxi, 910. The Vital Capacity in Hyperthyroidism with a Study of the Influence of Posture.
13. Higgins, H. L.: Amer. Jour. Physiol., 1914, xxxiv, 114. The Influence of Food, Posture, and Other Factors on the Alveolar Carbon Dioxide Tension in Man.
14. DuBois, Eugene F.: Basal Metabolism in Health and Disease. Philadelphia and New York, 1924.
15. Peters, J. P., and Barr, D. P.: Jour. Biol. Chem., 1920, xlv, 537. II. The Carbon Dioxide Absorption Curve and Carbon Dioxide Tension of the Blood in Cardiac Dyspnea.
16. Pearce, R. G.: Arch. Int. Med., 1921, xxvii, 139. The Cardio-respiratory Mechanism in Health and Disease.