OBSERVATIONS ON CARDIAC

REACTIONS TO EXERCISE

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OBSERVATIONS ON CARDIAC REACTIONS TO EXERCISE

Introduction .....Page 1

Historical..... " 11

Method..... " 17

Observations during exercise..... " 18

Observations after exercise..... " 28

Notes on effort syndrome..... " 35

Clinical notes on effort syndrome cases..... " 47

Notes on angina of effort..... " 61

Clinical notes on angina of effort cases....." 76

Bibliography....." 81

OBSERVATIONS ON CARDIAC REACTIONS TO EXERCISE

Introduction.

In the observations here recorded, my object was to observe the changes in systolic arterial blood pressure and in pulse rate, during and after muscular work, employing various loads and moving at various rates. The first group of experiments were performed on a number of University students, including men who were trained athletes, and who participated regularly in strenuous games. This part of the work was conducted under the direction of Professor E.P.Cathcart when I was McCunn Research Scholar in the Department of Physiology, University of Glasgow.

The second group consisted of patients whom I had treated in private practice over a period of fifteen years, and who were suffering from "effort syndrome", or, as it is now called "neuro-circulatory asthenia". Among those patients were several soldiers who were discharged from the Services as unfit and were receiving pensions for their cardiac disability. I had attended these men for several years before they joined the Services and I include notes on their medical histories prior to that date.

They were subjected to exercises and their pulse and blood pressure reactions observed.

The/

The third group consisted of patients who were suffering from angina of effort. A description of their symptoms and their subsequent histories, and their reactions to certain exercises, is appended.

Lewis (1) says "The simple conclusion that a man's capacity for work is ascertained more certainly by putting him to work and by watching his reaction, has been tardily accepted - even at the present time. The value of this method is by no means fully appreciated. If there are no clear signs of physical disease, judgement should form itself purely on the observed reaction to exercise."

Lewis's exercises in the "Soldier's Heart " (2) consisted of:-

(a) Walk briskly up forty stairs, one step at a time.
(b) Hop twenty times on each foot, raising shoulders six inches at a hop.
(c) Step up on to a fifteen inch chair twenty times.

"A subject enjoying health, will show in any of these tests, little respiratory reaction. The pulse rate rises no more than twenty to twenty-five beats per minute and will/

will resume its original rate within one and a half minutes. The respiratory rate is more important than the pulse rate. Take the pulse while watching breathing at the end of the test. In a person whose breathing is obviously disturbed by this test, or whose pulse rate rises by more than thirty beats and falls slowly, has a poor exercise tolerance. A further test could produce breathlessness. The best of these tests is the Stair Test, because it is the most customary form of exercise. It is the most convenient and the most used".

I employed these tests in Group II and Group III experiments.

Gillespie (3) in his series of experiments, says "There is no norma of response to effort, in the same subject there is variability from time to time, and the variability between individuals is even greater. It would appear that the individual differences are as important in the mechanics, as Haldane has shown them to be, in the chemistry of the circulation".

The experiments were an attempt to determine more exactly than has previously been done, the circulatory response of the heart to muscular effort, and so to furnish data, with which, in the future, the response of a disordered heart/

heart (whether the response be organic or functional) may be compared. Such data when supplemented by observation on subjects with cardio-vascular disease, during actual progress of work, should enable more confident estimations to be made of the performance capacity of abnormal hearts and to assess the patient's fitness for his daily task.

Accepted figures for the normal standards of human blood pressure have undergone considerable change since the introduction of the mercurial sphygmomanometer and the auscultatory method of measurement, and the tendency has been consistent of progressively lower standards to be established. The traditional formula of one hundred, plus the age in years, has been long abandoned, since this formula yielded figures for maximum normal systolic blood pressure in adults which were too high. Furthermore, this formula gave no indication of a range of normal figures and paid no attention to the diastolic pressure. For many years, 110 m.m. of mercury was accepted as the minimum normal systolic blood pressure in adults (Hall's (5) Dally 1929, Treadgold (6) 1933, Rook (7) and Dawson (8) 1938). All figures below this level were regarded as indicating hypotension, though McWilliam (9) (1925) held that "Roughly, anything decidedly below/

below 100 m.m. systolic, or 60 m.m. diastolic, may be suspected of being abnormal. It will be noticed in my cases that the average systolic blood pressure was 115 m.m. Most of the subjects were young men of twenty-one and all of good physique, and participating regularly in University athletic activities. A systolic blood pressure of 105 m.m. or less, disqualified from flying in the U.S. Army Air Corps in the period prior to 1936. (Snell (10) 1936). Subsequent regulations, however, permitted a minimum of 100 m.m. for flying duties (Rook and Dawson 1938). In all cases, of course, satisfactory results of general and special examinations were also required. However, the admission to flying duties of men with systolic blood pressure as low as 100 m.m. indicates a lowering of standards of normal systolic blood pressure. Alvarez (11) and Stanley (12) (1936), after examining thirty-six thousand fit prisoners in American jails, considered that 90 m.m. was the lowest limit of systolic blood pressure, and White (13) 1944, admits a systolic blood pressure of 95 m.m. to be normal. Robinson (14) and Bruce (15) (1939), after a very critical analysis of insurance figures, obtained from large numbers of persons in all age groups, arrived at the conclusion that the normal range of the systolic blood pressure was 90 - 120 m.m. for all adult ages. If these observations and analysis are accepted, and/

and there seems to be good ground for admitting their validity, all my cases must be considered normal in so far as their blood pressure is concerned. Hall's Dally in 1929, enunciated what he called "The biological law of hypopiesis", namely that low blood pressure, and he took 110 m.m. as the minimum normal systolic blood pressure in adults, is always to be regarded as an expression of a low vitality state. He holds that "Subjects showed to be of poor bodily build, thin and pallid with narrow chests and small elongated hearts", and that they were "Deficient in calcium and other vital salts". This seems to me to be typical of the kind of loose thinking which has clouded the subject in the past, and it has left an aftermath of opinion, which is not adequately supported by more critical observation and analysis.

Cambridge athletes were studied over a period of many years by Michell (16) (1909), who found that they frequently showed a resting systolic blood pressure of 95 m.m. Of sixty doctors and medical students, age eighteen to forty-seven years, examined by Chamberlain (17) (1930), fifteen showed a systolic blood pressure below 110 m.m. Of these, one suffered from cold hands and chilblains and one suffered from cold hands and what was called "neurasthenia". All the remainder were of good physique and health, and were athletic in greater or lesser/

lesser degree. Of twenty-eight Marathon runners in the Amsterdam Games in 1928, seven had systolic blood pressures (measured before the race and the subjects under optimum conditions) of 110 m.m. or less, and the third place was taken in the race by a man of thirty-one years with a resting pressure of 105/70 m.m. (By Bramwell (18) and Ellis (19) 1931).

In the records of my fifty effort syndrome cases, whose predominant complaint was of fatigue, lassitude, "fainting turns", "black-outs", dyspnoea, (etcetera) any explanation of which no organic lesion could be demonstrated, and of which emotional disturbance was held to be the cause, six had systolic blood pressures of 110 m.m. or less, with ages between twenty to forty-four years. Twelve had diastolic pressures of 70 m.m. or less, with ages between eighteen and fifty years, and the others had a systolic blood pressure within 126/80 m.m. range.

However, there is no indication from this submittedly small series that hypotension is any more common than hypertension in patients complaining of the symptoms commonly attributed to hypotension. White (1944) states that "In neuro-circulatory asthenia, blood pressure shows no typical abnormalities tending, on the whole, to be slightly elevated and variable".

The patients showing evidence of cardiac distress/

distress were given varying exercises, and the effect noted on blood pressure and pulse rate, and the time taken to return to resting level. These patients were observed over a period of fifteen years. I have included patients only where angina was a "clear cut" and definite symptom, associated in the high percentage of cases, with possibly organic cardio-vascular disease. It is impossible, in some cases, to prove during life that coronary disease exists, but in my opinion, angina of effort does not occur without coronary disease, except in certain cases of anaemia. The coronary disease may be severe or slight, and probably in some cases, does not cause obstruction to the blood flow in the resting heart, but produces its effect by interference with the normal stretching of the coronary arteries during exercise. Bourne (20) and Scott (21) state that "Angina of effort is not a dangerous symptom and patients do not die in the attack. The danger is only to be apprehended from the occasional occurrence of thrombosis from the results of atheroma of coronary vessels, or from vascular accidents."

Levine states"That the disability of the patient, who will complain in one form of myocardial disease, may be quite different from that of another. Dyspnoea is generally the most prominent symptom of cardiac failure, where it occurs in a patient with myocardial disease, but when there is localised coronary artery disease, producing angina/

angina pectoris, there may be no dyspnoea whatsoever, and only chest pain. Likewise, the heart muscle may be pathological as a result of hyperthyroidism without any dyspnoea. In this case, the heart is actually hyperactive and the primary complaint may be palpitation.

The inference of all this is - there can be no simple method of testing the health of the heart.

This explains why the various functional tests of the heart that have been devised, many of which are extensively used, have proved so unsatisfactory. Most of those tests utilise the effect of some effort on the heart rate, which has so many ways of expressing its abnormalities; it would be just as impossible to decide the brain is normal by finding that the hearing or vision is not disturbed. As a further illustration of this condition, a patient may have a history of severe syncopal attacks due to complete heart block (Stokes-Adams disease), and yet when put to a test of effort, will show no pain or dyspnoea whatsoever. The reason for this apparent anomaly is that the main disturbance of function in this particular instance is one of conduction. The other functions of the heart are essentially normal. Functional tests in current use are for the most part, tests of physical fitness and not of cardiac disease, and many individuals/

individuals with normal hearts, may manifest a poor response to effort, and contrariwise, those with definite well compensated heart disease, may show quite a normal or excellent response.

These are really due to the degree of physical training or to variations in nervous stability in different individuals, and do not measure the present or future status of the heart.

The above will suffice to throw some light on the present state of functional tests of the heart, and to indicate that the proper appraisal of problems of heart disease necessitates a complete survey of all the factors that may have any possible bearing on the situation.

HISTORICAL

Bowen (23) appears to have been the first systematically to investigate the changes occurring in blood pressure and pulse rate actually during muscular work. Edgecombe (24) and Bain (25) some years previously had made some preliminary observations in the same field. Bowen observed a sudden rise of pulse rate at the beginning of work, followed by a more gradual secondary rise. The secondary rise in the pulse rate continues until the work ceases, when the pulse rate falls suddenly and rapidly. This is followed by a slower secondary fall. The blood pressure also rises, though not so rapidly as the pulse rate, continued to do so for the first four minutes in exercise of thirty minutes duration, and then declining slowly during the remainder of the work. The fall in pressure after work is more rapid than the rise at its start, and continues without interruption to the normal and subnormal, and gradually returns to normal. Gillespie/

Gillespie also found this in his series of experiments. McCurdy (26) distinguishes three types of muscular exercise:-

1. Those of speed.
2. Those of endurance; long continued work of moderate severity.
3. Those of strength of maximal effort.

He confined his investigations to the last variety and found that the blood pressure rises considerably but is not accompanied by any great change in pulse rate, in some cases, an actual decrease being observed. Bainbridge (27) remarks that "The relationship between the rise of arterial pressure and the degree of muscular work has not been fully investigated and it is not known whether the arterial pressure varies directly with the severity of the exercise". Tigerstedt (28) says "You can almost say that the rate increases in direct proportion to the effort required and the extent and vigour of the movement". Boothby (29) believes that as a result of his experiments, that increased output of the heart is almost entirely effected by a rise in pulse rate. He considers that the pulse rate has a practically linear relationship to the intensity of the muscular work. Krogh/

Krogh (30) and Lindhard (31), however, found that the increase in minute volume of the heart during exercise in highly trained men to be affected to a much greater extent by increasing the output per beat, and to a much smaller extent by acceleration of the pulse rate than in the untrained. Means (32) showed, that after initial acceleration, the pulse rate remains almost steady, although the amount of work performed in a given time steadily increases. Bainbridge concludes that "In different individuals doing moderate exercise, the increase in output per minute may be brought about either by a larger output per beat, or a slight acceleration of the pulse, or by acceleration of the pulse with little or no increase in the output per beat; and that all graduations may exist between these two extremes.

Blood Pressure and Pulse Rate after Muscular Work.

Lowsley (33) found that after bicycle riding, the pulse rate falls more rapidly when the period of work is short and that it usually becomes subnormal immediately after prolonged exercise. The pulse rate was usually from sixteen to thirty-two beats above normal. The systolic pressure he found to show a slight rise, 10 mm., immediately after/

after moderate and long continued exercise (half to two hours), and following this, a drop to subnormal. This falls about equal to all types of exercise; in more exhausting exercise, there is a slightly greater fall. He observed that the systolic pressure returns from the normal to subnormal level more slowly after more rapid exercise. Cotton (34), Rapport (35) and Lewis, observed a fall in blood pressure in from three to ten seconds after exercise (lifting "dumb-bells"), followed by a rise to a maximum in twenty to sixty seconds, from which it falls below normal, from one to four and a half minutes. The pulse rate they found to be highest after cessation of exercise. Thereafter, it declined at first rapidly and then more gradually until the normal rate was reached and passed. Their conclusions were, that the changes in the amounts of work were less effective than the changes in the rate of work in producing changes in pulse rate (the last increment of pulse rate produced by increasing the rate of work being often exaggerated as full effort is approached), while the blood pressure is on the contrary less effectively influenced by changes in the rate of working than by changes in the amount of work done in unit time.

The Effect of Training.

Krogh/

Krogh and Lindhard believe that "The increased minute volume of the heart necessary in performing increased work, is obtained to a large extent by increase in the output per beat, and to a much smaller extent by acceleration of the pulse in the trained more than in the untrained". "Broadly speaking", says Bainbridge, "the acceleration of the pulse for a given intensity of muscular exertion, varies inversely with the contractile power of the heart, i.e. varies inversely with the degree of training. As the limits of exertion, however, are reached, the difference between the trained and untrained tends to disappear. The same writer holds that "During heavy muscular work, the venous inflow to the heart must be so large that every heart dilates almost to its full size during diastole, and the output per beat reaches its limits; the output per minute becomes directly proportional to the pulse rate. The different capacity of the trained and the untrained man to do work must depend, therefore, on the extent to which the pulse rate can increase". According to Bainbridge, the maximum pulse rate during exercise, whether the individual is trained or not, rarely exceeds one hundred and sixty. Benedict (36) and Cathcart (37) have recorded a pulse rate of a hundred and eighty in a highly trained subject, performing heavy work, and Gillespie found a pulse rate of a hundred and ninety-two/

two in one of his highly trained subjects, during very hard and prolonged exercise.

Schneider (40) noted the pulse rate and blood pressure immediately and after a brief exercise (fifteen minutes). They found that the tendency of the pulse to become subnormal two minutes after exercise, was less common in men with a slow standing rate. They found a quicker return to normal in the physically fittest. The systolic pressure was found to be increased immediately after exercise in seventy-five per cent of the cases, diminished in 9.9 per cent and unchanged in fifteen per cent. Two minutes after exercise, twenty-eight per cent were above normal, forty-four per cent were subnormal and twenty-seven per cent back to normal. Those with the normal pressure of more than 118hg.mm. showed a rise after exercise and those with the normal pressure of less than 118 hg.mm. showed a fall. Hill's subject showed a subnormal blood pressure, but a pulse rate still sixteen beats above normal one and a half hours after running four hundred and forty yards (Hill 41).

OBSERVATIONS

Method

The work was done entirely on the convertible Ergometer, devised by Cathcart, Wishart (38) and McCall (39), "the load" being from 0 - 5 kilogrammes. The rate of movements controlled by metronome varied from sixty to two hundred per minute. The experiments were done without exception on the high gear of the Ergometer. Work was done, as a rule, with one arm, the other arm having the sphygmomanometer attached. The sphygmomanometer used was one of the Tycos type, calibrated frequently by means of a mercurial manometer. The pulse rate was counted at the wrist as a rule, but, when very high, by auscultation over the carotid or apex beat.

EFFECTS OBSERVED DURING EXERCISE

The Pulse and its Variations with Load.

The pulse rate increases immediately exercise begins. The increase is very rapid at first, so that the rise from resting level to the maximum point for the whole period of exercise, (from thirty per cent in the case of heavy exercise of long duration to eight per cent in the case of light exercise of short duration) may occur in the first few minutes. A second and slow rise follows, which is greater or less respectively, according as the work is heavy or light. Nevertheless, the differences in the rise of pulse rate, which occur in accordance with work varying in severity, are more apparent in the rapid primary rise. Often in the slow subsequent increase, which occurs as work proceeds, it might be expected that in the course of exertion, a state of equilibrium would be reached, when the pulse would maintain a fairly constant level over a considerable period. This is not so, except possibly in the case of the lightest work, and in long continued and heavy work. The general tendency of the pulse rate is upward until the end. The highest/

TABLE I : Varying the Load.

Subject.	Load in k.g.	Resting		Maximum during work.		Maximum % increase over resting level.		Maximum reached in Min.	
		P.R.	B.P.	P.R.	B.P.	P.R.	B.P.	P.R. Min.	B.P. Min.
H.McL.	.5	72	118	94	140	30	18	5½	13
	.6	70	112	112	140	45	20	12	7
	1.0	74	116	114	146	54	25	17	8
	1.1	80	116	138	160	72	37	18	12
	1.2	76	122	140	168	82	37	17	11
	1.5	74	120	148	170	100	41	21	8½
	1.8	70	118	150	170	113	43	22	20
	2.0	78	114	186	186	137	62	20	18
A.T.M.W.	.5	72	106	86	122	19	15	10½	8
	.7	68	112	92	136	35	21	14	12
	1.0	64	116	94	146	46	25	12½	12
	1.5	70	110	108	152	54	42	20	16
	1.8	72	114	130	172	80	50	18	14
	2.0	72	106	168	188	133	69	24	13½
D.M.H.	.5	80	118	100	136	25	15	8½	12
	.8	78	116	110	138	41	19	7	14
	1.2	80	118	116	140	45	19	12½	10
	1.5	80	120	116	156	45	30	16	16
	1.8	76	118	140	180	84	52	21	15
	2.0	74	122	160	182	129	46	20	15
H.G.	.5	70	120	94	132	34	10	7½	8
	.6	68	110	102	140	50	27	12	10½
	1.0	70	116	112	160	60	38	8	12½
	1.2	80	120	138	172	72	43	14	7½
	1.5	68	122	152	176	123	44	17	18
	2.0	68	120	158	178	150	48	20	18

Duration of Exercise - 30 minutes. Rate of Movement - 100 per minute.

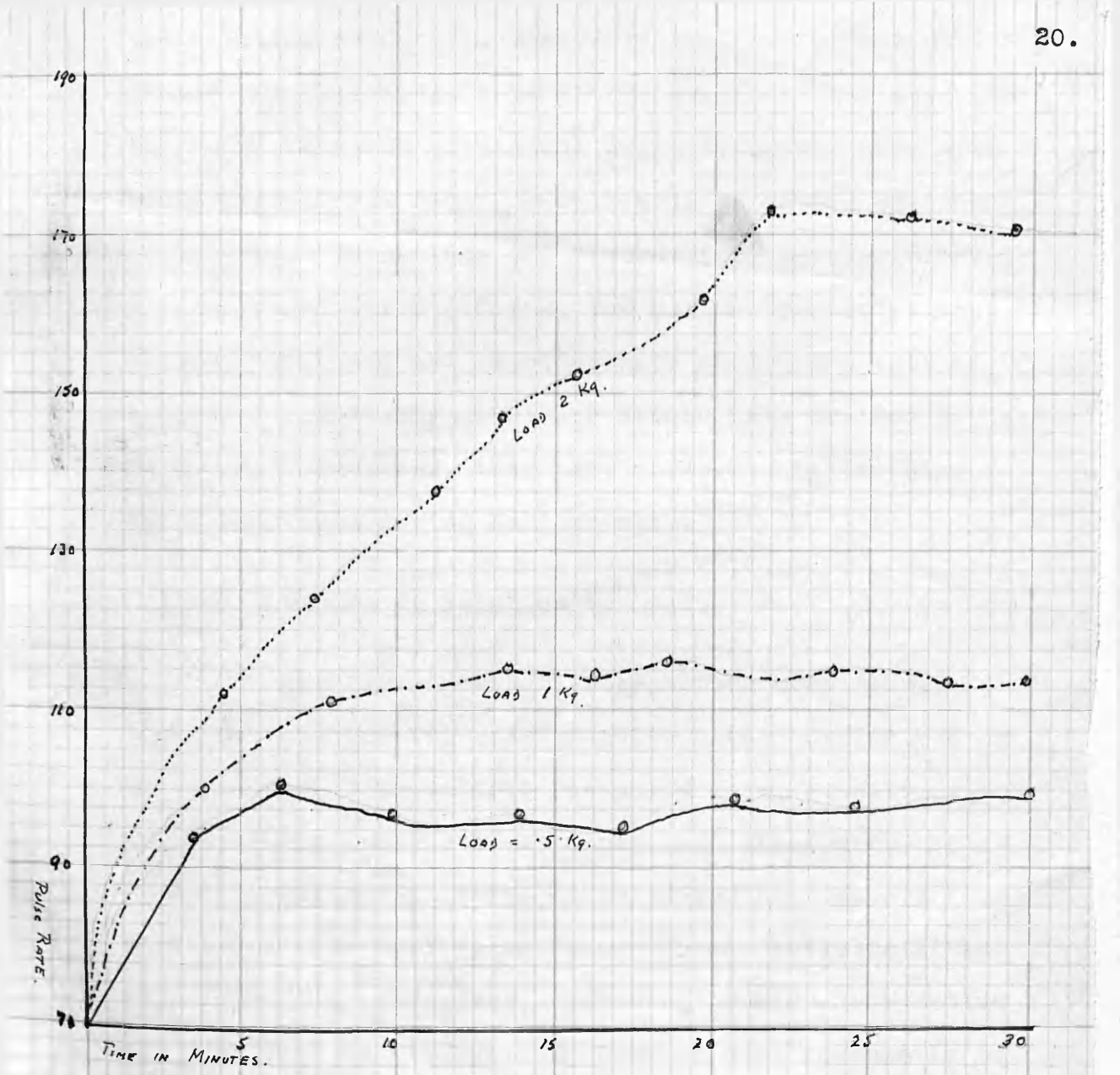

Fig. I. (Subject H.M^cL.) Pulse rate during exercise with various loads.

highest pulse rate attained increases with the load; the relation is not, in the individual subject, a strictly linear one. Thus, in some of the cases, it was seen that the pulse tends to accelerate proportionately more with heavy loads. Few data are available as to the maximum pulse rate. Bainbridge and Pembrey (42) both considered a hundred and sixty (160) as the maximum for efficiency, although Cathcart and Benedict have recorded a rate of a hundred and eighty (180) per minute in a trained subject. On several occasions, they have observed higher pulse rates than this during hard exercise.

Blood Pressure in Relation to Load.

The blood pressure rise occurs more slowly than does the primary rise of pulse rate, but instead of continuing to rise as does the pulse rate, it attains a maximum point comparatively early, and afterwards, falls gradually and irregularly. Lowsley and some others have attributed this fall to fatigue. In our subjects at the time this fall took place, there was no sign, subjective or objective, of fatigue. It is much more reasonable to suppose that it is due to the opening up of very numerous capillaries in the working muscles. It is interesting to find that the pressure sometimes falls below the pre-existing/

existing resting level at the beginning of an experiment. This is difficult to explain unless due to a deep inspiration, which may occur at the beginning of work. The time taken by the pressure to attain its maximum is variable, varying from three and a half to twenty minutes in exercise of duration. There is no invariable relation between this time and the magnitude of the load.

The rise in blood pressure is approximately proportionable to load, neither the absolute increase in blood pressure, nor the percentage increases, nor the percentage increase over an assumed constant resting level shows a directly linear relation to the load. The response of the blood pressure in a given individual varies a good deal, so that a smaller load may be accompanied by a much greater increase than a heavier load on the same or different day.

Progressive Change in Rate During Exercise.

Owing to the general tendency of the pulse rate to rise during exercise, the influence of successive increments on the load of the pulse is not very clear and distinguishable. The increase of blood pressure, however, can be said to follow closely each successive increase of load made during the course of a single period of work. Anomalous/

TABLE II : Pressure with Progressive Increase of Load During Work.

Subject	Resting B.P.	Load In Kilogrammes.												
		.1	.2	.25	.3	.4	.5	.6	.75	1	1.5	1.75	2	2.5
H.McL.	118	126	126	128	130	132	140		150		170		210	230
	120	130		138		140		142		160		180		190
	116	122		136	140	142	150	156	160	160	170			196
	118	130	138				148		170		176		180	
	120	126	140	146		148	156			172				200
	116	128	136		140			162			170		190	
	120	132	142	150		158			168			178		198
	122	135	146		152		160		178	182		190	200	220
A.T.M.W.	106	116	120			140		146			168		178	
	112	122	130	140			152		154					
	114	122	134	146	140	150		156		160		168	174	178
	118	126	132	142	146		150			152			168	
	108	130	136	138	146	150			158	160	168			
D.M.H.	110	128	136	146	150		154	158		168		174	180	
	116	128	132	148	146		148	148		150		166	180	
	118	130	138											
	112	132	142	146	156	160	162	162		168				
	114	124	130		150		160			174		190		210
H.G.	108	120	132	148		148		150		162	168			
	120	130	140	150	156		158	160		164	172	180		198
	118	128	136	148	160	166			168	170		180	188	
	120	126	132	146	160		160		168	172	180			230
	116	130	140	150	156	160	164	170	170	178			180	190
	118	128	132	140	150	162			180		184		190	198

Anomalous results are so rare that when occurring, they may be attributed to unknown and accidental factors. With successive decrements of load, the blood pressure falls in steps, which correspond fairly closely; in our observations, correspondence would have been closer had sufficient time been allowed always for the blood pressure to reach its maximum for a given load before passing to the next; the fall which, in any case, occurs as work progresses, also interferes.

Load in kg. Rest ..	2.5	2.0	1.75	1.5	1.25	1.0	0.75	0.5	0.25	0.0
Exp.1 ... B.P.95 ..	130	165	163	155	142	130	136	130	122	108
" 2 ... B.P105 ..	162	163	166	162	152	153	145	140	130	...

When the load is decreased during exercise, the pulse rate does not necessarily decrease correspondingly.

Load in kg. Rest ..	2.5	2.0	1.75	1.5	1.25	1.05	0.75	0.5	0.25	0.0
Exp.1 ... P.R.72 ..	102	100	100	104	100	100	100	100	100	98

TABLE III : Varying the Rate.

Subject	Work Done		Resting		Maximum during work.		%increase in Resting Level.		Max. reached in Mins
	k.g.	Rate	P.R.	B.P.	P.R.	B.P.	P.R.	B.P.	B.P.
H.McL.	1	80	68	112	110	132	61	17	7
		100	72	120	124	156	72	30	12
		150	74	124	160	168	117	36	14
		200	68	122	164	192	141	56	15
	1.5	100	70	108	120	140	71	29	11
		150	72	118	168	164	134	38	8
		200	80	120	182	180	127	50	13
	2	60	74	124	148	170	100	36	10
		100	68	118	188	180	176	52	8
		200	70	118	210	196	193	66	6½
A.T.M.W.	1	100	82	112	124	136	51	21	7
		150	70	118	130	156	85	32	11
		200	68	116	180	170	150	50	5
	1.5	100	74	122	129	150	74	23	11
		150	74	120	172	168	132	40	14
		200	76	118	180	188	137	59	10
	2	80	68	116	142	178	108	53	12½
		100	70	118	170	180	142	52	10
		200	72	120	198	198	174	65	7¾
D.M.H.	1	150	80	112	140	156	75	39	4
		200	74	120	202	178	172	48	4½
	1.5	100	82	118	146	136	76	15	16
		150	74	120	180	156	142	30	17
		200	80	118	198	190	147	61	8½
	2	80	80	118	182	168	121	42	10
		100	72	120	182	178	152	49	8½
H.G.	1	100	74	120	132	140	80	16	4½
		150	80	118	180	156	125	32	6½
		200	74	120	184	178	150	48	4½
	1.5	100	76	124	150	152	97	22	5½
		150	74	118	172	168	131	42	11
		200	76	124	190	188	140	43	9
	2	80	80	120	170	150	112	25	12
		100	72	118	192	180	166	52	10½
		150	74	120	196	202	164	68	8

Load in k.g. Rest ...	2.25	2.0	1.75	1.5	1.25	1.0	0.75	0.5	...
Exp. 2 .. P.R...84 ...	105	100	100	101	110	100	98	106	...

This may well be due to an interfering tendency, the tendency of the pulse to rise in the course of exercise.

Varying the Rate of Work.

The pulse is directly proportional to the rate of work. The influence of the rate of work is evident from the start. The precentage increase in pulse rate is also directly proportional to the work rate, and individual differences are evident. The blood pressure rises more, the faster work is performed. It is apparent from the Table that the time taken for the blood pressure to reach its maximum is usually greater with higher rates of working.

Pulse Rate Immediately Following Work.

TABLE IV

Subject	Maximum P.R. During Work	Pulse Rate in 10sec.periods Following Work.			
H.McL.	132	124	112	100	92
	156	134	128	114	100
	168	152	126	120	104
	192	172	160	142	130
	140	126	118	102	92
	164	140	122	116	100
	180	168	142	132	116
	170	153	130	116	102
A.T.M.W.	136	108	114	108	100
	156	148	136	136	120
	170	142	120	118	110
	188	164	142	130	126
	198	172	160	156	138
D.M.H.	156	118	112	108	94
	160	140	128	114	108
	172	146	136	118	116
	163	146	138	128	120
H.G.	132	116	108	98	92
	150	120	112	108	106
	170	152	148	136	122
	184	158	140	142	132

EFFECTS OBSERVED AFTER EXERCISE

The Relations between Rate and Pressure During and after Exercise.

The readings which were taken for successive periods of ten seconds show plainly that while, as is generally conceded, the pulse rate immediately after exercise is a fairly reliable relative indication of the rate of the pulse during the preceding work, it is impossible to draw inferences therefrom as to the absolute rate of the heart during exercise. Even in the first ten seconds after work, there is a considerable drop. The importance of comparing readings taken at a given interval after work ends, is also evident from the Table.

The following Table shows that the correspondence between the maximum blood pressure attained during muscular work, and that occurring within thirty seconds of the cessation of work, is very slight.

Varying the Load.

From the Table it is evident that the pulse rate

one/

Blood Pressure During and After Work Compared

TABLE V

Subject	Work Done		Resting	Max.	After end if work	
	kg.	Rate	B.P.	B.P.	B.P.	Time in secs.
H.McL.	1	100	118	146	120	20
	1.5	100	120	176	138	15
	1.5	80	118	170	140	10
	2	100	118	180	142	15
	2	60	120	184	150	10
	2	100	120	184	160	10
	2	100	122	160	132	15
	2	180	120	172	140	15
	2	180	120	180	150	15

one minute from the end of exercise, the rate being counted during the period between fifty to seventy seconds from the end of work, bears a direct relation to the load, against which the work has been done, the duration of the work period and the rate at which the work was done being uniform throughout the series of experiments. It will also be seen from the Table that there is a tendency on the part of the pulse to reach a subnormal level within fifteen minutes, where light or heavy loads are used; but the time taken to reach a given level is longer the heavier the load.

It appears that the blood pressure one minute after work ceases, is as a rule higher after work with greater loads and, since the work-periods for a given subject are approximately equal, after greater amounts of work. (Table Vl). The minimum value reached within fifteen minutes is very similar with all loads:-

Subject	H.McL.	A.T.M.W.	H.G,
Mean value of lowest reading of pressure ...	85.4	90	86
Mean variation	2	1.0	2.5

The/

VARYING THE RATE

TABLE V1

Subject	Work Done.		Resting		Maximum during work.		At the end of work.		One minute later		Minimum reading		Reaction from end in Minutes *		15 mins. from end.
	k.g.	Rate	P.R.	B.P.	P.R.	B.P.	P.R.	B.P.	P.R.	B.P.	P.R.	B.P.	P.R.	B.P.	P.R.
H.McL.	1	80	68	112	110	132	110	126	88	108	80	82	5	4½	86
	1	100	72	120	124	156	120	148	100	102	82	82	6	3½	88
	1.5	180	74	124	164	192	158	190	132	146	76	90	7	4½	92
	1.5	90	68	108	160	188	160	180	138	140	90	80	8	5½	84
	1.5	120	70	118	168	194	158	194	126	148	100	96	10	4	90
	2	100	72	120	182	186	178	178	132	136	98	82	12	3½	98
	2	180	80	124	216	196	200	186	150	152	100	80	10	2½	106
	2	180	74	118	208	212	210	214	152	158	96	94	10	2	108
A.T.M.W.	1	100	82	112	124	136	120	130	92	110	82	90	2	2½	84
	1.5	120	70	118	128	156	118	146	98	102	96	92	6	4	86
	2	80	68	116	180	170	184	174	120	134	102	94	10	5	106
	2.5	160	74	118	190	198	184	180	145	148	102	84	12	5½	112
H.G.	1	80	72	124	132	146	130	132	100	102	78	82	3	2½	76
	1.5	100	76	118	150	152	142	142	100	106	86	80	7	4	80
	2	100	72	120	190	188	194	180	146	132	86	92	8	5½	90
	2.5	150	80	120	192	180	188	186	130	114	98	92	12	4	106
	2.5	160	74	118	196	202	190	194	142	122	104	84	14	5½	112

* P.R. - Lowest value reached.
* B.P. - First subnormal reading.

The mean variations are very small, especially in view of the fact that the load varied two or three hundred per cent.

Varying the Rate of Work.

Since the pulse rate during work is directly proportioned to the rate of work, and since the pulse rate after work indicates the pulse rate during exercise, it follows that the pulse rate after exercise is higher when the rate of work has been greater. This is borne out by the Table. It is clear that the pulse rate returns more slowly to normal when the rate of work has been greater, the lowest rate during fifteen minutes observation being reached later as the rate of work increases.

One minute after work has ended, the pressure is constantly higher as the rate of work has been faster. The minimum pressure reached in fifteen minutes is very similar for rates varying three hundred per cent ... This can be seen as follows:-

Subject	H.McL.	A.T.M.W.	H.G.
Average of minimum values	86.4	94.2	94.6
Mean variation	2.1	3	2.2

The minimum pressure reached in this time bears no relation to the rate of the previous exercises.

Varying the Amount of Work.

Where the amount of work done in a given time is varied, by changing the load or rate of work, or both, in a series of experiments in a given individual, the pulse rate one minute after exercise as a rule is directly related to the amount of work that has gone before, as is evident from the Table; likewise, the greater the work, the slower is the return of pulse rate to a resting value.

Fully Trained Athletes.

Twenty athletes from the University Athletic Club, all playing two Rugby matches a week, and, therefore, presumably in first class training, were subjected to an exercise for thirty minutes - at rate 120 and load 1.5 kg. It was observed that in every case, there was a subnormal average dip of 15 mm., and the time taken to return to normal was noted at the conclusion of the exercise. There was no evidence of distress or fatigue.

FULLY TRAINED ATHLETES.

TABLE VII

Subject	Load in k.g.	Resting		Maximum during work.		Time taken to return to normal after work ceased.		Min. B.P.
		P.R.	B.P.	P.R.	B.P.	P.R.	B.P.	
J.A.M.	1.5 k.g.	58	110	150	170	4	3	80
W.W.W.	1.5 k.g.	65	120	160	160	4½	4	92
A.T.W.	1.5 k.g.	72	116	120	148	6	3½	100
J.A.M.	1.5 k.g.	60	126	110	150	4	5	110
J.W.	1.5 k.g.	72	110	122	142	3	4	98
A.T.R.	1.5 k.g.	68	120	120	146	5	4	98
J.McF.	1.5 k.g.	76	112	128	150	4	4½	110
R.M.P.	1.5 k.g.	64	124	110	148	6	4½	108
T.R.M.	1.5 k.g.	66	140	122	160	7	5½	96
H.G.	1.5 k.g.	70	126	110	156	4½	4½	114
H.D.	1.5 k.g.	72	130	114	152	4½	5	108
R.A.B.	1.5 k.g.	74	98	116	138	5	5½	90
H.R.G.	1.5 k.g.	76	112	112	146	5½	5¾	98
J.G.	1.5 k.g.	68	116	110	154	4½	5	100
T.A.	1.5 k.g.	68	124	108	148	5	4½	110
P.M.L.	1.5 k.g.	72	116	102	136	5¾	5	118
W.S.	1.5 k.g.	65	104	112	160	5	5½	100
T.R.S.	1.5 k.g.	72	124	140	142	4½	5½	90
D.P.	1.5 k.g.	74	120	116	162	4½	5½	98
J.R.S.	1.5 k.g.	70	118	118	148	5	4	94

NOTES ON
EFFORT SYNDROME

The term "effort syndrome" does not imply disease, but refers to symptoms which are normally brought on by effort, but in this case, the effort is inordinately slight. The symptoms affect both the central nervous system and the cardio-vascular system. The condition has been known for many years, and was, at one time, though to be primarily a war-time condition, and has been the result of much speculation and a considerable cardiological literature. The condition was first described by Maclean (45) in 1867, when he gave a description of "Tumultuous action of the heart". He stated that it was pathological and described it as due to spots he found on the pericardium. In 1871, Da Costa (46) described three hundred and seventy-one cases in the American Civil War. In the 1914-18 war, the condition was first described as "Disorderly action of the heart", and was thought to be pathological. Lewis was first to deny this and he directed attention to the nervous system; he described it as an/

an "organic neurosis".

In every ten patients admitted to Cardiac Hospitals during the 1914-18 war, nine were suffering from functional disorders, most commonly effort syndrome (Lewis 1940). Since Da Costa's description in 1871, the condition has been reviewed by Fraser (47), Wood (48) and Dunn (49), showing the reorientation that has taken place since the first World War. During then, physical phenomena were analysed in great detail, but the emotional factors in aetiology were disregarded and the stressing of occasional cases, in which a similar symptomatology were associated with early organic heart disease, led to complete neglect of such early papers as adduced evidence for a psychogenic basis.

Paul Wood (1941) presents a comprehensive review of the literature clarifying the mechanisms of symptom production. The present fairly general acceptance of this syndrome as a typical psychomatic disorder, autonomic expression of a clinical demonstrable psychoneurosis, usually of chronic anxiety type, rests not only on the absence of a demonstrable structural basis or organic sequelae, but also on certain positive features. First, there is nothing specifically military about the condition; in/

in most Army cases, its onset preceded service, and it is common in civilian life amongst women and children. The evidence suggests a higher incidence in emotional races, and the clinical condition is usually associated with the evidence of predisposition to neurosis in both personal and family histories, and with personal inadequacy characterised particularly by abnormal physical timidity. A careful history reveals that the characteristic cardiac manifestations are but a part of the more extensive and multiple symptomatology, which usually includes cold blue extremities, rapid irregular breathing, sighing, sweating of the emotional distribution, tremor, dizziness, headaches and a dry mouth, with their concomitant physical signs. These symptoms reveal a widespread autonomic disturbance of central origin, and as in the case of the cardiac symptoms themselves, the whole picture resembles much more closely the normal physiological response to fear, than an effort response to exertion (Wood 1941).

It is worth noting also that the relations of symptoms to effort is highly selective, and marked influenced by the patient's emotional attitude to the exertion concerned; and that early organic heart disease is by contrast usually symptomless.

The/

The term "neuro-circulatory asthenia" has been finally employed in this country, (Oppenheimer (50) and associates 1918), and this remains at the present time the most satisfactory designation because it expresses its abnormal character by referring to both the neurasthenic state and circulatory symptoms, and, at the same time, it does not limit the term "effort", or "irritability" or "soldier", or make it too general by calling it by the vague inclusive designation "cardiac neurosis", which is simply one type of cardiac neurosis or of irritability of the heart. It occurs in civilians as well as in soldiers; it results from excitement as well as from effort and it is not a normal response to ordinary effort. Also, its symptoms are not exactly like those produced by effort in a normal healthy person.

It is impossible to state accurately the frequency of neuro-circulatory asthenia for several reasons. The borderline is very wide and indistinct, and where normal response ends and the subnormal response begins, especially with such variable factors as human individuals, it is impossible to say. Moreover, a normal person may have the condition for a short time during or after an acute illness, especially fatigue, without its being particularly noted by/

by the patient or doctor, and finally, it has been included by most practising physicians as part of the more general terms "neurasthenia", "nervous prostration" and "neurosis".

"Long experience has shown that soldiers suffering from effort syndrome are unfit for military service. There is little tendency to spontaneous improvement and methods of treatment so far applied, have failed almost completely in restoring fitness for complete service". ((Wittkower (51), Rodgers (52) and Wilson (53))).

The known facts about effort syndrome, collected during and after the last war, have been recorded by Lewis, Fraser and Grant (54) (1940). Unanimity has not been reached as to aetiology. Some investigators attributed it mainly to infection, or exotoxic or endotoxic influence. The existence of emotional factors in some cases is generally admitted. (Lewis, 1940, Oppenheimer and Rothchild (55) 1918). Wittkower states that "As "personality types", effort syndrome cases are all males with an overkeen sense of duty, anxious always to do what they considered their moral obligation. Taking an everyday view of their personalities, they would be regarded as valuable members of the community and the characteristics they displayed, would be assessed as virtues." He states that "These characteristics are found to be the early difficulties over/

over instinctual drives, which, for some reason, has aroused an undue sense of guilt; in other words, there is an internal compulsion against which they cannot rebel".

Breathlessness was the most common and most troublesome symptom, and the psychologists state that most of the effort syndrome patients, prior to its onset, show gross nervous symptoms of a phobic nature. They state that the breathlessness of effort syndrome is the psychological correlate of what appears, in the psychological sphere, as fear of suffocation (Claustrophobia). One of the constant facts in determining the occurrence of effort syndrome, is the pre-existence of what is known as the character disorder, i.e. a group of allied psychological characteristics, not regarded with anxiety by the patient, but, nevertheless, a definite indication of undue sensitivity to the emotional stress of a specific nature. Since these character disorders regularly ante-date effort syndrome, it appears legitimate to regard it as a psychological condition. Among the precipitating factors, emotional disturbance was commonest, and was found to be a continuance of upsets, which had occurred in civil life.

Over-exertion was found preceding the onset of symptoms, where a repressed or obsessional drive to overcome/

come physical inferiority was a manifestation of a basic character disorder.

With the onset of effort syndrome, it is common to find depression (loss of interest and apathy), and disproportionate exhaustion, which is the physiological correlate of depression. Rodgers and Wilson state that concealed aggressiveness play a part in the production of symptoms, and results in self punishment and masochistic attitudes. Allied to this and equally unrecognised by the patients, the onset of effort syndrome may, secondarily, be utilised by men of the obsessional type as an honourable retreat under a "smoke screen" of physical symptoms from painful failure in military life.

Effort syndrome, may, occasionally, occur in the form of episodes from which the patient makes a spontaneous recovery, but, for the most part, it is a chronic disorder.

The following cases I encountered in practice. All of them had been discharged from the Army suffering from effort syndrome. They had been under my care for twelve years before joining the Army and continued under observation after their discharge. In no single case was there sufficient evidence to permit a diagnosis of structural disease. Such symptoms as breathlessness and palpitation on abnormally small degree of effort, were common to them all. Grant states/

states: "That the diagnosis of cardiac disease on those signs alone, is, at best, uncertain and a matter of opinion, and that, prognostically, such signs are of no significance, and that their chief value lies in directing attention more closely to the cardio-vascular system for the detection of other and more reliable signs of disease".

Effort syndrome cases reviewed by Grant five years after discharge from the Army, showed that the incidence of cardiac disease was no more than one per cent, and it is felt that incipient cardiac disease cannot be regarded as an underlying cause for effort syndrome in all but a negligible proportion of cases. He found that reaction to exercise was found to be the most satisfactory basis for the military prognosis of effort syndrome, and the younger the patient, and the better his exercise tolerance, the greater his chances of recovery. Thus, both age and exercise tolerance must be taken into consideration in the prognosis of effort syndrome. The following case had a complete cardiological investigation:-

Dyspnoea was the most frequent symptom with cardiac pain, fatigue while at rest, dizziness, palpitation, sighing respiration, headache, sleeplessness and numbness accompanying it. The dyspnoea, cardiac pain, palpitation and fatigue, were complained of after slight effort in all cases/

cases.

In eight of them, these symptoms existed while at rest, and they complained of wakening up at night and feeling suffocated, and with definite precordial pain. The pain was described by these patients as "like the stab of a knife", and in others, only as discomfort, with a "fluttering" in the chest. Apart from fatigue on exertion, they all showed general lassitude in the morning. The cases which joined the Army and were subsequently discharged, were of the emotional, unstable type and while in civilian life, were constantly seeking medical advice for trivial complaints. After discharge, I had them under observation and recorded an improvement in their condition. It would appear that the release from Army service removed a powerful stimulus to the exaggeration of their symptoms, and by permitting them to resume their accustomed habits and occupations, tended to render them less sensitive to unfitness. Their exercise tolerance was measured for several months and this showed a continuous and steady improvement.

It was observed in my group of patients that there was frequently an unhappy home background with a family history of "nervous breakdown". Invariably, there was a history of illness in childhood, and of having been pampered/

pampered later; or again, there may have been a "murmur" found in childhood and undue emphasis put on it, the child being a victim of iatrogenesis. Thus, undue convalescence may lead to the condition, but, alternatively, too short a convalescence from an infection sometimes definitely predisposes to the illness. Three main groups were observed in practice:-

1. The man of good physique, who has been labelled delicate in childhood. He becomes, as a result, delicate in his own idea and is "ill" equipped, physically and mentally, to deal with life's problems. He is "flabby" as a result of overcare, and on conscription, suffers from a sense of injustice, so that on any slight precipitating strain, he develops the condition.

2. The person of poor physique, who is alert and introspective, a typical product of the large cities.

3. The patient who develops the condition after too short a convalescence from infection. These mostly clear up spontaneously.

Diagnosis

The patient has usually an anxious facies and the/

the pulse rate is rapid. There is unusual and excessive sweating, signs of arrhythmia, and extra systoles are common. The pulse invariably "settles" after a time. The apex beat is forcible and there is often an area of hyperaesthesia around it. The sounds are usually pure, and, if there is a systolic murmur present, it is not propagated and it alters with exercise. The blood pressure is probably raised to begin with, but it invariably drops during the course of an examination. Exercise tolerance is probably of little value in assessing heart disease generally, but in this case, it may be of some value in assessing the nervous control of the heart. It was found in the course of treatment, over a period of fifteen years, that those in Groups I and II require reassurance and graduated exercise. Group III require rest in bed to convalesce adequately. In Groups I and II, I discovered that rest in bed is the very worst treatment that can be prescribed.

The following is an analysis of the symptoms of which my patients complained. They were usually elicited spontaneously and were often described with "gusto". In the analysis of the fifty cases here recorded, thirty-five per cent of them were women.

Undue/

Undue dyspnoea on effort	80%
Chest pain	55%
Palpitation	40%
Dizziness, "black-outs" and faints ...	36%
Undue fatigue on exertion	16%
Headaches, undue sweating, backache, globous hystericus, joint pains	10%
Sighing respirations	90%

Chest pain: This is usually in the left mammary region. It is a dull ache of long duration and occurs at rest as well, when there may be sharp stabs.

Dizziness, "Black-outs" and Faints. It was noticed that in the "black-outs", patients never completely "pass out" or fall and hurt themselves.

Undue fatigue on exertion. Tiredness is an unusual complaint, whereas, in organic heart disease, it is very common.

CASES OF EFFORT SYNDROME

Case No.1

J.H. - Age 28

This man was an only child, he had a strict upbringing and led an extremely conservative life. He was unmarried and was very attached to his mother. There is no history of note prior to his Army service, apart from an attack of influenza. He was anxious and keen to enlist, as he said, "to do his bit". The first two years of Army service was uneventful, but on receiving promotion, he states he began to find himself getting anxious about his job. He felt inadequate, and not a suitable person to command other men. Prior to this period, he never reported sick and said he was in perfect health, but he noticed in battle training that he could not keep up with the others. He observed that he was increasingly breathless and sweated easily, his sleeping was irregular and he felt "washed out". He was admitted to Hospital and investigated, and subsequently he was discharged with the label "Effort Syndrome", and stated to be unfit for Army service.

When/

Case No.1.Contd.

When I saw him on his return to civil life, he still complained of inframammary pain, breathlessness and palpitation. I could detect no abnormality in his heart apart from tachycardia. The resting level of his pulse was 128 per minute, his sytolic blood pressure 120 m.m.Hg. and diastolic 80 m.m.Hg. He was markedly dyspnoeic on being given exercise, which consisted of running up a flight of eighteen steps until the occurrence of his pain. Immediately following the exercise, his pulse rate was a 190, and the systolic blood pressure 160. His systolic blood pressure resting level was regained in eight and a half minutes, but his pulse rate was still a 130 after thirty minutes. At no time did his systolic blood pressure become subnormal after exercise.

His genefal condition improved over a period of six months. At first he reproached himself for his inability to "fight for his country", but he became more placid and settled down to his peace-time occupation. His exercise tolerance improved progressively every month. At the end of six months, his sytolic blood pressure resting level was regained in six minutes, but/

Case No.1.Contd.

but his pulse rate continued to be above a hundred and his dyspnoea became less marked.

After one year, the patient was normal and there was no evidence of any physical cause of his cardiac condition. Both X-ray of the chest and his E.C.G. were normal in every respect. At the end of eighteen months, his exercise tolerance was much improved, his resting systolic blood pressure from the same exercise was regained in five minutes and his pulse rate was normal after the same interval. For the past six years, there has been no recurrence of his symptoms.

Case No.2.

T.L.G. - Age 33.

Before "joining up", this patient was of the obsessional type. He was over anxious about his own health and that of his family, which consisted of a wife and two children. His physique was good, but he was convinced that he was suffering from tuberculosis of the lungs. No amount of reassurance could convince him until he was X-rayed, and the plates shown to him that there were no abnormalities in his lungs. His social and family history was good, although there was a neurotic element in two other members of his family, a brother and a sister; both his parents were normal.

He "joined up" in 1940 and I did not see him again until he was discharged in 1943 from a military hospital with the diagnosis of "Effort Syndrome" or "Neuro-circulatory Asthenia". He told me that during his service in Egypt and in the Western Desert, he had suffered from no illnesses, his only sick parade was for a septic finger. He first noticed his breathlessness after a long spell of active service during the advance into the desert, and he stated that during that time, he had been anxious and worried about the welfare of his family at home. He reported sick with precordial pain, getting/

Case No.2 Contd.

getting much worse when he continued working, and disappearing when stopping work. He states he had a vague feeling of uneasiness the whole time he was in the desert, and yet he said he never shirked anything. He was in Hospital in Cairo and returned to England, where he was discharged in 1944.

No abnormality was observed when I examined him, his E.C.G. was normal, but his exercise tolerance was not good. His systolic blood pressure resting level was regained in twelve minutes, and his pulse rate in ten minutes. At no time during his exercise did his systolic blood pressure become subnormal after exercise.

In the course of the next few months, his breathlessness and precordial pain improved, and he said he felt much better and was obviously glad to be home in civilian life again. Two years later, his exercise tolerance was tremendously improved and he complained of no other symptoms.

Case No.3.

W.G. - Age 30.

This patient, who had previously been under my care for several years, enlisted at the outbreak of war. His family life was normal and his medical history good. He was a prominent Church worker, and in any public service, he was a willing participant. His moral standards were very high and he could be described, psychologically, as of the George Washington-Calvin Type. His home life with wife and family was apparently happy and satisfactory.

He "joined up" in 1939 and seemed to"fit into" military life at first. I saw him on one of his leaves, and he was complaining of palpitation, and said he found the training difficult. But, at no time did he give one the impression that he disliked the life or questioned the purpose of his being in the Army. He went to France and was evacuated from Dunkirk. Shortly afterwards, I heard that he was in Hospital, and within six weeks, he was discharged as suffering from "Effort Syndrome". He had been examined by Army Psychologists when he was complaining of breathlessness, persistent pain behind the sternum on walking, palpitation, sweating and insomnia.

When/

Case No.3 Contd.

When I examined him, his exercise tolerance was extremely poor. He stated that the cardiac pain was severe and that it was impossible for him to undergo even the simplest exercise. His resting systolic blood pressure was regained in twenty-five minutes, and his resting pulse rate in eighteen minutes. At no time during the exercise did his blood pressure reach subnormal level. Over a period of six months with regulated exercises and long rest periods and the resumption of light work, he improved considerably. At the end of two years, he never complained of his precordial pain and his breathlessness, and palpitation and sweating were only elicited on very strenuous exercise. For the last four years, his health has been normal; his E.C.G. and X-ray of the chest showed no abnormality.

Case No.4.

R.S.B. - Age 31

This man was an only child, aged thirty-one, and was the sole supporter of his parents before he "joined up". He was very anxious about their welfare. He was a nervous re-active type, although he had no serious illnesses during the six years I had attended him. He was always complaining of "not feeling well". He had made several attempts to avoid going into the services, but was classified A.1. and was sent to the Army. I understand his military service was uneventful until he met with an accident by falling from a motor vehicle and fracturing his ankle. This "hospitalised" him for a time, but eventually, he returned to his unit and was allocated light duty. He noticed then, his breathlessness, palpitation and sweating on the slightest exertion. He was referred to Hospital and he states that his breathlessness had now become painful, the pain radiating down the arm from behind the sternum. Coincident with this, his ankle was also causing him some pain, and a diagnosis of osteo-clastoma and efforts syndrome was made, for which he was eventually discharged on pension. When I saw him, his cardiac symptoms were stillmanifest, his exercise tolerance/

Case No.4 Contd.

tolerance was poor, his systolic blood pressure returned to normal in twelve minutes, and his pulse rate in sixteen minutes, after running up and down stairs twice. He was obviously glad to be home and his condition improved progressively when he returned to work and resumed his normal civilian pre-occupation.

Within four months, his recovery rate was back to normal. During the next six years, there had been no recurrence of his cardiac pain.

Case No.5.

A.T. - Age 24.

This patient was of poor physique. He "joined up" at the outbreak of war and was a very keen and good soldier. He was aware of his physical inferiority and overcame that by over-driving himself. After a particular strenuous week or battle training, he first noticed his breathlessness and palpitation, and pain in the chest, with no definite distribution. He found it so painful that he reported sick although he was unwilling to do so. He was admitted to Hospital and investigated, and after a period of six months, he was discharged as suffering from "Effort Syndrome".

In this case, his compulsion to overcome his physical inferiority was undoubtedly a factor in this case, amounting to an acute anxiety state. When I saw him, although he was markedly dyspnoeic, his precordial pain had disappeared. His exercise tolerance was at first bad, his systolic blood pressure resting level being regained after moderate exercise in twelve minutes, and his pulse rate in ten minutes. At no time after exercise did his systolic blood pressure become subnormal. After rest in bed for one month and carefully graduated exercise, this/

Case No.5 Contd.

this patient soon recovered. He resumed his work, and for the last six years, has had no recurrence.

Case No.6.

Mr.W. - Age 34.

This man was a nervous type of slim build, apparently calm, with evidence of nervous instability, e.g. profuse and unreasonable perspiration, patches of alopecia, intolerance, irritability with his wife and family. All this abnormal behaviour began with the war, when he was anxious to avoid military service. To prevent this, he joined the special Constables in 1939. Previously, he had been a commercial traveller and was accustomed to carrying cases long distances. His wife noticed an alteration in his temperament - he became increasingly more irritable and bad tempered, and was thoroughly unhappy in his work. In September 1940, he was posted to guard an aerodrome and had to carry a rifle and respirator. He found the job very monotonous although it meant a certain amount of vigilance. He started to get a pain in his chest in July,1941. The pain was sharp and stabbing in character and "came on" at the apex of the heart. It radiated round the lower ribs and into the back, and down the left arm. It bore no relationship to food. At times, he stated, the pain had no relationship to exercise, for example/

Case No.6 Contd.

example - he could dig his garden without any pain, but found when he was carrying his rifle at the trail, the pain was considerable. He also used to cycle to work, a strenuous job, and at the beginning he did not have any pain, but ultimately, he was unable to do this, the pain used to come on earlier and earlier in his shift of duty, until it eventually became continuous. When the pain was established, he could not carry his rifle, it would simply "drop out of his hands." He states he slept very badly and was not refreshed. His weight went up from ten stone and eight pounds to twelve stone and three pounds, and then came down to eleven stone, when his pain developed.

He was taken off his out-door duty and put on an inside job, but the pain still continued. He was very breathless and while the pain was on, he stated he had to take short quick breaths because he felt he could not get sufficient air into his lungs. He was examined by the police doctors and after a long period in bed, was discharged as suffering from "Effort Syndrome", but when I saw him, I could detect no abnormality in his chest or heart. He was very breathless on the slightest exertion, and after sufficient exercise to precipitate his pain, his/

Case No.6. Contd.

his pulse rate rose from ninety-two to a hundred and forty-six and it took twenty minutes to regain its resting level. His systolic blood pressure at rest was a hundred and thirty and after exercise 146. This returned to normal in seven minutes with no subnormal dip.

After a long rest in bed and gradual rehabilitation as regards his peace time occupation, he recovered; for the last six years, he has had no recurrence.

NOTES ON ANGINA OF EFFORT

The pain in angina of effort is usually retro-sternal and not pre-cordial. The coronary insufficiency is evidenced by a symptom so important that it has practically been recorded as a disease entity ever since it was given the name "angina pectoris" by Heberden (43) in 1768.

The only other clear evidence of coronary insufficiency that we possess, consists of certain electro-cardiographic abnormalities, which constitute the most important information which clinical electro-cardiography affords us.

Angina of effort consists of a sensation of paroxysmal pain, usually under the upper or middle sternum, brought on by exertion, persisting for a few minutes and frequently radiating to the arms. The definite clinical picture provided by the different varieties of cardiac pain are so clear and distinct, that it is believed that the mechanisms vary in each individual type of pain.

Since/

Since, at the moment, it is quite impossible to determine minor and transitory changes in the coronary circulation by any other means, a careful scrutiny of the symptomatologies is an essential method of approach to the problem. There are several possible organic causes for the symptoms of angina of effort, presupposing the symptoms to be the result of interference with the coronary flow during exercise; coronary atheroma and syphilis of the aorta, interfering with the coronary flow, are the commonest causes. Furthermore, cases have been described where severe anaemias were associated with angina of effort, and where no evidence of cardio-vascular disease was found at necropsy (Cabot (44)).

By "angina of effort" is meant a cardiac pain, generally arising centrally or to the left of the sternum, sometimes radiating to one or both arms, to the neck and face, and occasionally, to the back, which has an exact quantitive relation to the exertion.

In a given amount, exercise will produce the pain and cessation of exercise will be followed immediately by a progressive diminution and disappearance of the pain. The pain never comes on at rest, except for the following exception/

exception - severe emotion will produce it, and, since emotion is associated physiologically with an increase in the heart rate and raised blood pressure, the pain does appear under these conditions. Spasmodic angina is often instituted by exercise, but on the cessation of exercise, does not entirely disappear, but may become less severe. Also, coronary thrombosis may come on during exercise, especially if the thrombosis is a small one, onset is sudden and the pain may continue for days, and then become considerably less and frequently disappear. Thus, angina of effort would appear to be the type of pain most associated with a chronic organic lesion, interfering with the coronary circulation.

The presence of coronary thrombosis can be diagnosed electro-cardiographically, and by the history of a severe attack of continuous precordial pain lasting several days, and only relieved by morphia.

It was noted in my series of cases that the onset of angina of effort preceded in a large percentage of the cases, an attack of coronary thrombosis.

A point that needs to be stressed is that death in an attack of angina of effort is not recorded, and, therefore, it would seem to be that angina of effort is not a dangerous symptom, but that it is an indication of

a/

a greater or lesser degree of coronary disease. Dyspnoea on exercise of a severe degree was more than common in patients who subsequently died, but not enough evidence was obtained on the presence, absence or the degree of dyspnoea resulting from exercise so as to be helpful in the prognosis of cases.

The cardiac prognosis ultimately depends on whether or not a fatal coronary thrombosis is likely to develop, and on the state of the ventricular muscle. Difficulty arises in assessing the integrity of the latter or the amount of safe exercise a patient can undertake. This exercise, of course, is restricted by the cardiac pain. It was observed that some patients can undergo far greater exertion without suffering pain and this was reasonably the most prognostic point obtainable. In all my cases, full history and clinical investigation was undertaken in the past history. The following points were specifically investigated:-

Rheumatic fever, chorea, "growing pains", scarlet fever, tonsillitis, diphtheria, syphilis and previous mental stress.

The symptoms investigated were:-

Pain, dyspnoea, sighing respiration, orthopnoea, feeling/

feeling of constriction, palpitation, exhaustion, cough, giddiness, dyspepsia, catamenia, frequency of micturition, the character of the pain, its position and radiation, and its relationship to exercise and emotion.

The patient's description of his own pain was universally of a "gripping" or "cramping" character. The exercises they performed were equivalent to Lewis's grade I type, but at the onset of pain, the exercise was terminated. The resting levels of the systolic pressure were taken and the systolic pressure on cessation of work, and the time taken to regain the resting level with an intervening subnormal dip.

The "after histories" are noted in the Tables of the cases, all of whom died from coronary thrombosis at various intervals after the first onset of pain. In every case, electro-cardiographs taken in Hospital had shown a degree of coronary insufficiency.

TABLE VIII

Name	Age	Type of Pain	Resting S.B.P.	After Exercise S.B.P.	Time to return to Resting Level.	Subnormal Dip.	History Pain First Appearance.	After History.
A.G.K.	47	Gripping.	150	190	35 min.	Nil	1940	Died 1944.
N.M.	42	Stabbing.	126	148	40 "	"	1940	" 1946.
M.S.S.	55	Gripping.	170	200	12 "	"	1938	Still alive.
G.B.	48	Knife-like.	140	160	10½ "	"	1936	" "
S.R.T.	38	Dull ache.	146	176	24 "	"	1944	Died 1945.
J.K.	62	Gripping.	176	200	10½ "	8 .mm.Hg.	1940	Still alive.
Mr.J.M.	64	Gripping.	170	196	22 "	"	1936	Died 1940.
T.M.	49	Like toothache	170	210	7½ "	"	1936	Died 1938.
H.K.	54	Very severe.	166	220	21 "	"	1935	" 1940.
D.R.P.	49	Unbearable.	120	160	12 "	10 mm.Hg.	1940	" 1946.
G.C.	60	Gripping.	140	180	15½ "	Nil	1942	Still alive.
Mr.R.F.	64	Gripping.	180	210	17 "	"	1939	" "
A.N.D.	45	Tight.	140	200	36 "	"	1939	" "
A.L.N.C.	57	Gripping.	170	240	21 "	"	1940	Died 1940.
M.T.	54	Stabbing.	150	196	18 "	"	1944	" 1946.
F.C.	63	Shooting.	128	180	8 "	8 mm.Hg.	1944	" 1944.
T.W.	70	Gripping.	140	176	15 "	Nil	1938	" 1947.
F.G.	62	Cramping.	120	200	26 "	"	1944	Still alive.
A.O.	54	Gripping.	156	180	10 "	"	1940	" "
W.T.P.	52	Cramping.	136	170	22 "	"	1946	Died 1947.
U.S.	59	Unbearable.	172	210	24 "	"	1936	" 1941.
M.K.	58	Unbearable.	180	240	12 "	4 m.	1937	Still alive.
B.L.	44	Gripping.	146	160	17 "	Nil	1941	" "
W.V.	60	Gripping.	140	176	10½ "	"	1942	Died 1942.
J.L.L.	62	Cramping.	170	210	12 "	"	1944	" 1946.
J.E.	48	Stab-like.	160	200	26 "	"	1940	" 1941.
F.P.	44	Cramping.	172	210	20 "	"	1938	" 1945.
R.G.T.	47	Gripping.	148	160	17 "	"	1938	" 1940.
K.M.	53	Gripping.	190	240	18 "	"	1941	Still alive.
W.G.	48	Gripping.	176	196	21 "	"	1942	Died 1944.
F.P.	51	Cramping.	170	210	12½ "	8 mm.Hg.	1942	Still alive.
R.M.	50	Knife-like.	162	200	12 "	"	1936	Died 1941.
M.G.	47	Gripping.	170	210	18 "	"	1941	" 1942.
R.C.	51	Gripping.	146	180	16 "	"	1942	" 1945.

CASES OF ANGINA OF EFFORT.

Case No.1.

Mr.A. - Age 52.

This well built man, inclined to stoutness, first complained of a "crampy" type of pain in the second left interspace, which radiated slightly into the epigastrium. He stated that it was brought on by excitement and exertion, in circumstances of stress, or after a meal. The pain was relieved immediately by rest. He was fifty-two years of age, and whilst carrying on his peace time job, acted as an A.R.P. control officer. He found that during an"alert", the pain came on almost every time. He stated that, during the attack, his breathing was normal, and he found that a deep breath did not alter the pain in any way. When I examined him, his heart rate was sixty, regular and no adventitious sounds. His blood pressure was 110/80 after sufficient exercise to "bring on" the pain, his blood pressure rose to a hundred and forty and his pulse rate to eighty. It took seven minutes for his pressure and pulse to return to normal with no subnormal dip. E.C.G.showed evidence of coronary insufficiency/

Case No.1.Contd.

insufficiency. The patient was found to be a diabetic. Insulin was found to be essential. On treatment, his pain disappeared and his maintenance dose was twenty units P.Z.I.daily.

Case No.2.

Mr.A.R.B. - Age 42.

This man's past history showed evidence of a rheumatic infection when eight years of age. He was in bed for three weeks. He stated that he has been quite well until now, when he stated he had a pain in his chest. The pain varies in character, but it is usually "stabbing". He actually feels it in his heart rather than in his chest wall. At the beginning, the pain was felt at the axilla, and later on, he felt the pain more at the apex. He could feel the heart "beating on the spot". The pain does not radiate, and may last for a considerable time, but it is definitely relieved by rest. It "comes on" usually when he is tired. On examination, his heart rate was sixty-nine, pulse of good tone and normal in rhythm. His blood pressure was 130/90. After sufficient exercise to bring on the pain, his blood pressure was 170/90 and his pulse rate 120. His resting levels were regained without subnormal dip in fifteen minutes. He has no history of allergy, varicose veins, haemorrhoids, palpitations, headaches, dizziness or dead fingers. He has two brothers who have similar types of pain, and his grandfather and father both died in their early forties. There/

Case No.2 Contd.

There seems to be a history in this family of vascular vulnerability. His E.C.G. showed evidence of previous coronary thrombosis .

The patient had another attack, and died of coronary thrombosis, two years after first complaining of his precordial pain.

Case No.3.

Mrs.W. - Age 57.

Past history good. She is a very nervous and highly strung patient and has been easily upset by air raids. She complains of a pain in her left breast, of a "tight gripping" character. She says she has noticed slight degrees of pain there for the last five years and remembers it starting while she was nursing her father. She seems to get two distinct types of pain - firstly, round the line of the diaphragm, anteriorly, and may radiate down the left arm. This pain may last for several hours and is brought on by fatigue or excitement. The onset of the pain may be delayed for about an hour, and then again, may come on through the night after an especially exacting day. She gets exhausted very easily and flatulence can cause this pain, although a deep breath does not seem to affect it. Now secondly, she gets a pain in the region of the second rib, on the right side two inches from the midline. This pain is of short duration and is more likely to spread down the left arm. A deep breath, stooping or mild exercise, produces this pain immediately. If she gets a bad fright, e.g. bombs, this pain comes on, associated with tachycardia, and then later/

Case No.3 Contd.

later, the first pain will develop. Her heart is regular, no murmur present, rate seventy-five, blood pressure 140/90, pulses soft and the vessels are normal pulpation. After exercise sufficient to bring on the pain, her blood pressure was 170/110, pulse 110. Her resting level was regained, with no subnormal dip, in thirty-five minutes. This pain was relieved by nitroglycerine, but the attacks became more frequent. E.C.G. showed evidence of previous coronary thrombosis. She was found to be suffering from pernicious anaemia. She reacted to liver therapy and improved considerably, but her pain remained on exercise, but with less intensity.

Case No.4.

Mr.W. - Age 55.

Past history showed acute rheumatic fever when fifteen years old. He is a well built man, highly strung and has been carrying on an exacting and worrying job for a long time. Lately, owing to war-time, these anxieties have increased, When I examined him, he was complaining of a "sharp stabbing" pain over his apex, radiating upwards and down the left arm; he has a systolic murmur at the aortic area - systolic blood pressure 150/100, pulse rate 72. He stated that the pain is brought on by exertion and emotional upset. He states it comes on while asleep if he dreams that he is involved in a fight, which he does frequently. The pain wakes him up and he has to sit up in bed for relief. Throughout the day, the pain lasts for five minutes, but is definitely relieved by exercise. His exercise tolerance was bad, the pain being brought on very quickly. His pulse rate was 100 and blood pressure 160/110, regaining normal, with no subnormal dip, in twenty-two minutes. His E.C.G. showed evidence of a previous coronary thrombosis. His pain lasted/

Case No.4 Contd.

lasted for ten minutes. This man carried on, taking limited restricted exercise, but he died of coronary thrombosis, two years after the first onset of the pain.

Case No.5.

Mrs.M. - Age 59.

This woman was a vigorous housewife, who stated that she had never been ill apart from her four confinements. She first felt a "tightness" across her chest two years ago, but lately, the pain had become "gripping" in character, and much more incapacitating. The pain did not radiate and was relieved by rest. It was a typical angina and she reacted to nitroglycerine. E.C.G. showed evidence of coronary disease. Her heart started to fibrillate and reacted to digitalis and rest, but, on getting up, her attacks were more frequent. She continued for two years like this, until she developed pneumonia and died.

C O N C L U S I O N S

1. The cardio-vascular response to muscular effort, as measured by heart rate and blood pressure, is very finely adjusted to the degree of effort.

2. The reactions in the cardio-vascular system, depending on load and rate, in the performance of muscular work, may be gauged from the inspection of the changes in blood pressure and pulse rate, during and after work.

The variations in pulse rate and blood pressure are comparatively slight in equal amounts of work in equal time within a wide range of rate and load, but, on the whole, a moderate rate with a moderate load produces a somewhat smaller increase in blood pressure and pulse rate than the same amount of work, in the same time, with a very fast rate and a comparatively light load (or a slow rate with a heavy load). This conclusion is confirmed by the conditions of blood pressure and pulse rate following work.

Conclusions Contd.- No.3

3. The time relations of the fall in pulse rate after work are more important than the actual magnitude of the pulse rate after work, as a relative indication of the rate of the heart during the actual progress of exercise. The magnitude of the blood pressure after work, is, at best, only a relative indication of the height to which the pressure has risen during work. The time relations of the fall in blood pressure are not of the same significance as those of the fall in pulse rate for the estimation of the cardio-vascular changes during the preceding work. On the whole, the pulse rate during and after exercise was more closely related to each other than the corresponding blood pressures. The variability of the relations between the pulse and pressure changes during work, and those existing after it, even to identical condition of load and rate, make it necessary that observations such as those recorded, should be many times multiplied before it can be hoped to estimate even approximately the variations occurring during work from those observed after it.

4. Blood pressure and pulse rate resting levels and/

Conclusions Contd. - No.4.

and reactions to the same exercise, varied from day to day in the same individual. There was no normal response observed in any subject throughout the experiments.

5. Exercise tolerance tests in effort syndrome have little value in recognition of the present or future status of the heart, or indeed, in assessing myocardial efficiency; yet they are valuable in judging the nervous control of the heart rate. The examiner must not overlook the natural tachycardia or nervousness, especially when it "dwindles" as the interview proceeds, and during recumbence, which is essential to every cardiac examination.

Where a high pulse rate persists, for example, over one hundred, the thermometer may explain it, or the state of the throat or lungs. Re-examination after an interval may be indicated if the rate persists well over a hundred throughout the interview and after recumbency. The high rate of persistent tachycardia can be one expression of a neurosis, and judgement as to fitness may have to depend on the state of the nervous system than that of the heart.

In the group of cases recorded, no definite conclusions/

Conclusions Contd. - No.5

conclusions could be drawn from the state of the pulse rate and blood pressure before and after exercise, the only noteworthy fact was that at no time after exercise did the systolic pressure reach a subnormal level. In every case of effort syndrome, there showed a remarkable increase of pulse rate while performing light exercise. The systolic blood pressure was not raised in any case by an appreciable amount. This would suggest that no great muscular effort was involved before fatigue ensued, and that there was no immediate arterial or capillary dilatation in the active muscles. The whole phenomena seemed to be of nervous origin.

6. It was noticed that in the highly trained athletes after cessation of work, there was a subnormal dip with a quick recovery rate in every case, and it was also observed that the average systolic blood pressure in these subjects, was never less than 118Hg.mm. This quick recovery rate might be interpreted as an indication of myocardial efficiency and of the general vaso-motor tone of the subject.

7. Angina of effort is a "clear cut" and definite/

Conclusions Contd. - No.7.

definite symptom, associated in a high percentage of cases with cardio-vascular disease. The diagnosis of angina pectoris can be, and often must be, made solely from what the patient tells us; the patient's story is the foundation of the diagnosis. From the results of the exercises, the conclusion is that they can have little value in the recognition of myocardial or valvular disease, or indeed, in assessing myocardial efficiency. It was also observed that the cardiac pain assimulating coronary disease, exists in some cases of anaemia, diabetes and hyperthyroidism.

Coronary disease may only produce this pain by interference with the blood flow, by stretching of the coronary arteries during exertion. It was noticed that exercise tolerance gave little help in assessing the prognosis of coronary insufficiency in the group of cases under review. The older patients seemed to live longer, on an average of five years, after the first attack of anginal pain.

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