THE RELATION OF HEART WEIGHT TO THE BASAL METABOLISM AS VARIED BY THYROID ADMINISTRATION

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The administration of active thyroid material is followed (1) by an increase in the weight of the heart. This study was carried out to determine the relation between this increase in weight and the basal metabolic rate of the organism as a whole.

Methods

Several groups of male albino rats 80 days old were placed upon modifications of a diet (2) which contained 0, 0.06, 0.12, 0.18, 0.24 and 0.30 per cent of dessicated thyroid (Wilson Laboratories), respectively. After 105 days on these diets the rats were starved for 24 hours and their basal oxygen consumption measured under chloretone anesthesia in the manner described by Dock (3). The animals were then sacrificed and the heart and kidneys removed and weighed. A number of the rats on the diets containing the higher thyroid concentrations succumbed before the end of the experiment.

RESULTS

The data for the individual rats have been tabulated in Table I and in Fig. 1 heart weight and basal oxygen consumption, both in relation to body surface, have been charted. There is a definite linear relation between these two factors.

DISCUSSION

It is our belief that in general there is a direct relation between the heart weight and the work which this organ performs. The work of the heart as measured by the cardiac output is determined by two factors. One of these is the basal metabolic rate of the entire organism as measured by the oxygen consumption. In normal subjects Grollman (4) found that the basal cardiac output is proportional to

TABLE I

No.	Thyroid in diet	Body weight		Body surface	Basal oxygen consumption per 100 sq. cm. body surface per min.	Heart weight per 100 sq. cm. body surface
		Original	Final			
	per cent	*gm.*	*gm.*	*sq. cm.*	*cc.*	*mg.*
1	0	155	284	490	0.71	165
2	0	168	281	487	0.78	134
3	0	137	274	478	0.79	159
4	0	141	287	494	0.83	180
5	0	149	286	492	0.83	166
6	0	126	302	511	0.85	153
7	0	149	308	518	0.85	162
8	0	138	282	488	0.86	152
9	0	126	278	483	0.87	156
10	0	142	288	495	0.89	161
11	0.06	154	246	445	1.19	192
12	0.06	150	246	445	1.19	191
13	0.06	142	230	426	1.22	190
14	0.06	176	270	473	1.27	225
15	0.06	135	230	426	1.31	228
16	0.06	138	246	445	1.33	197
17	0.06	127	227	422	1.36	229
18	0.06	149	240	437	1.44	212
19	0.06	140	220	413	1.78	241
20	0.12	142	218	411	1.58	226
21	0.12	180	235	432	1.62	265
22	0.12	150	250	450	1.62	231
23	0.12	148	210	402	1.82	279
24	0.12	153	195	382	1.93	309
25	0.18	130	218	411	1.75	270
26	0.18	125	167	344	1.74	247
27	0.18	143	184	368	1.85	259
28	0.18	140	212	404	1.88	286
29	0.18	150	190	375	2.16	296
30	0.18	148	188	373	2.17	291
31	0.24	144	207	397	1.94	269
32	0.24	147	204	394	2.15	286
33	0.24	151	198	386	2.30	279
34	0.24	188	212	404	2.44	323
35	0.30	132	193	379	2.06	315
36	0.30	150	165	341	2.28	313
37	0.30	140	198	386	2.30	311
38	0.30	123	178	359	2.48	303

the body surface which makes it proportional to the basal metabolic rate. Fullerton and Harrop (5) have reported a close relation between the elevation of the basal metabolism and cardiac output in hyperthyroidism in man. The second factor which determines the

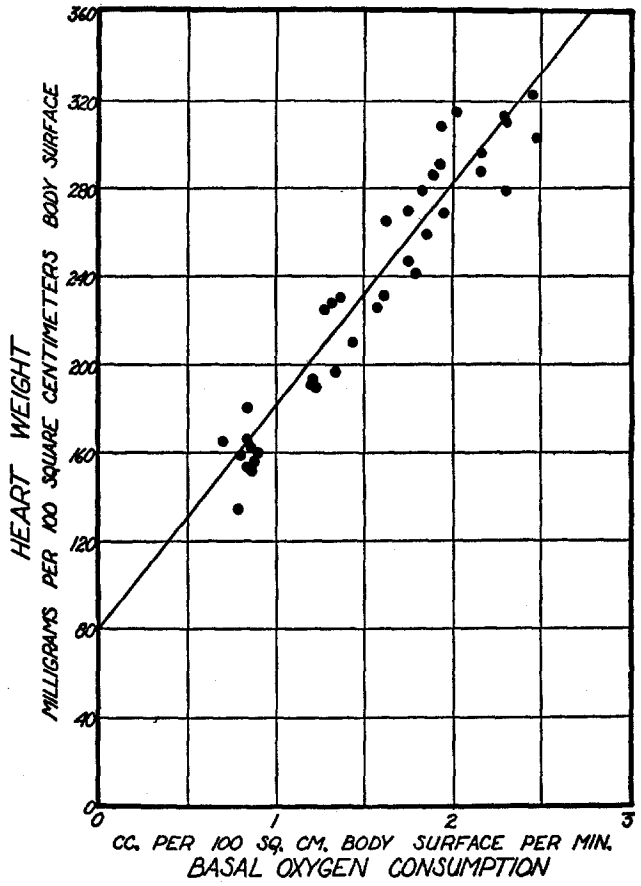

FIG. 1

work of the heart is the sum of those conditions which increase both the basal oxygen consumption of the entire body and the cardiac output above the minimum levels. These are primarily bodily movement or exercise and to a lesser extent the ingestion of food (6), psychic disturbances (7) and other minor factors.

Considered in the light of cardiac work as we have described it here the relationship in Fig. 1 might be interpreted as indicating the effect of these two factors determining the work of the heart. The heart weight at the theoretical zero oxygen consumption would be that due to the influence of those factors such as exercise, and so on which are responsible for the cardiac output above the basal level and would be essentially the same in all the rats. The linear relationship between the heart weight and oxygen consumption beyond this point would represent a direct relation between weight and the work produced by the cardiac output in its dependence on the basal metabolic rate of the entire organism. If this conception is true the cardiac enlargement incident to thyroid administration must be a simple work hypertrophy of the muscle. Although this is contrary to the generally accepted idea of the effect of thyrotoxicosis on the heart most of the critical evidence supports such a view. It is very questionable for instance (8) whether hyperthyroidism alone ever produces cardiac failure and no myocardial pathology was found to result from either clinical thyrotoxicosis (8) or experimental thyroid intoxication (9). The water, sodium and potassium contents of the cardiac muscle remain constant as the muscle bulk increases under the influence of thyroid (10). The accumulation of lactic acid which occurs (11) in the experimentally thyroxinized heart at the expense of the glycogen content might be interpreted as opposing this view if considered a result of myocardial injury. However this occurs in hearts which have been under a terrific strain of rapidly increasing work of unusual amount and may it not perhaps be analogous to the accumulation of lactic acid (12, 13) with the oxygen deficit incurred by the skeletal muscles (14) when they are given an unusual or excessive amount of work? It is possible that just as training enables the organism as a whole and hence the skeletal muscle to reduce the excess of lactic acid produced by a given effort stimulus (15), the administration of thyroid over a long period would enable the cardiac muscle or its oxygen supply to adapt itself to the unusual condition and prevent the accumulation of lactic acid. Observations upon this point are now in progress.

SUMMARY

A linear relationship exists in the albino rat between the heart weight and the basal metabolic rate when varied by the administration of active thyroid material. It is suggested that this increase in heart weight which follows the increase in metabolism after thyroid is in the nature of a simple work hypertrophy of the myocardium.

Addendum.—Data in a manuscript by Dock and Lewis[1] which came to our attention after the completion of this manuscript brought up the question of the validity of our implied assumption that the basal oxygen consumption as measured under chloretone anesthesia

TABLE II

Group	No. rats	Average body surface	Per 100 sq. cm. body surface		
			Food per day	Heart	Basal oxygen consumption per min.
		sq. cm.	*gm.*	*mg.*	*cc.*
1A	5	536	1.77	157	0.81
1B	5	491	2.09	160	0.84
2A	5	445	2.85	202	1.26
2B	4	426	3.17	224	1.44
3A	5	415	2.98	262	1.71
3B	3	386	3.78	268	1.79
4A	3	372	4.16	282	2.06
4B	3	374	3.97	309	2.26
5A	4	395	4.53	289	2.21

with an environmental temperature of 28.5°C. is directly related to the 24 hour basal heat production during life. The authors mentioned point out that at an environmental temperature of 19–21°C. this is not necessarily so, as part of the heat due to thyroid replaces the normal heat formation to maintain body temperature. However our rats were kept at a temperature usually from 24–26°C. and the basal metabolic rate seems to vary directly with the total daily heat production of the unanesthetized animals as measured indirectly (Table II) by their food intake. Fig. 2 shows that there is also a

[1] Dock, W., and Lewis, J. K., *J. Physiol.*, 1932, in press.

linear relationship between food intake and heart weight. This strengthens the view that heart weight is directly related to total metabolism and hence to volume flow of blood.

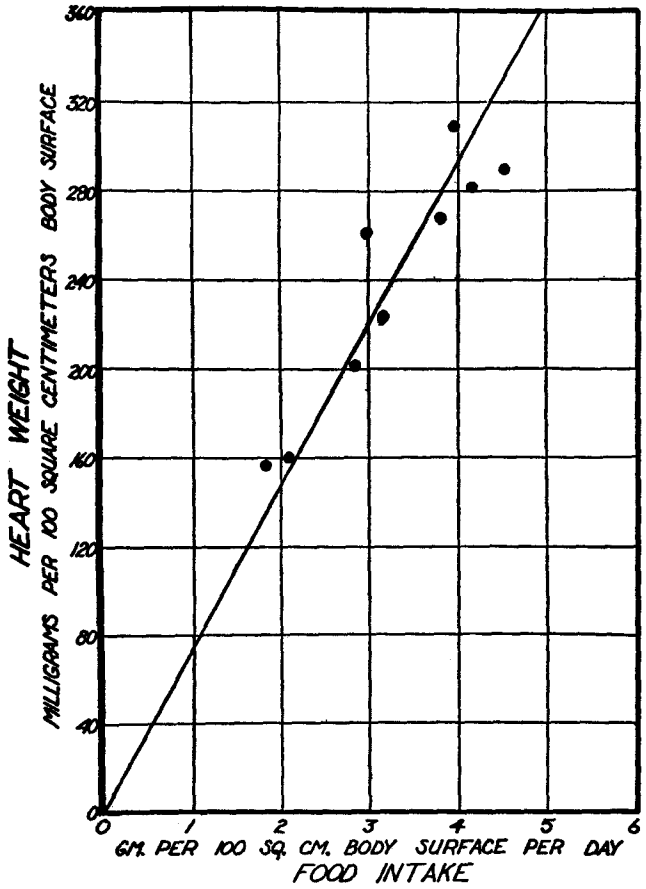

FIG. 2

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