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METABOLISM OF CHILDREN UNDERGOING OPEN-AIR TREATMENT, HELIOTHERAPY AND BALNEOTHERAPY.

BY

LEONARD HILL, M.B., AND J. ARGYLL CAMPBELL,
F.R.S., M.D., D.Sc.

(FROM THE NATIONAL INSTITUTE FOR MEDICAL RESEARCH, HAMPSTEAD.)

With the Co-operation of

SIR HENRY GAUVAIN, M.A., M.D., M.C.

In consideration of the beneficial effect of heliotherapy in the treatment of tuberculosis attention has been turned almost entirely to the influence of the ultra-violet rays, which do not penetrate more than 0.1 mm. (F. E. Barnard), being absorbed by the surface film of the skin; and (perhaps) more justly to the luminous rays, which, in part, penetrate and are absorbed by the blood and deeper tissues. Other factors of great importance must also be taken into account—namely, the effect of the cooling power of the open air on the exposed body in stimulating muscle tone and body metabolism; the effect of breathing cool air with low vapour tension on promoting evaporation from the respiratory membrane,¹ and so enhancing the outflow of secretion from it and the flow of lymph and arterial blood through it; the effect of cool air in promoting evaporation from and flow of lymph through sores and discharging sinuses; the effect of sunshine in promoting such evaporation and flow, and in warming diseased parts exposed to it. In this paper we propose to consider the effect on body metabolism.

In published results² it was shown that body metabolism or heat production of healthy adults was raised by sitting quietly out of doors in the shade for half an hour on an ordinary winter's day, and that shivering was not necessary to raise metabolism. We found that a cooling power between 15 and 20, as measured by Hill's dry kata-thermometer, gave the proper conditions for avoiding shivering for our subjects, who wore the same clothes as indoors.

To continue our observations on the effect of open air, and at the same time to investigate that of heliotherapy on body metabolism, we carried out a number of experiments at Lord Mayor Treloar's Hospital at Alton, and Hayling Island, Hampshire, during the past summer. In the present paper we record these results.

The conditions at this hospital were particularly suitable, our subjects being children with surgical tuberculosis, treated, among other methods, by open air and heliotherapy. After a course of skilful training the children are able to lie naked in the open air for many hours under atmospheric conditions which would soon make an ordinary healthy individual shiver and uncomfortable unless wearing his ordinary clothes. The process by which the children are inured to exposure is a gradual one and takes a longer time in some cases than in others.³ Sir Henry Gauvain,⁴ the medical superintendent, has described the method as employed at Alton.

Methods.

We used the Douglas-Haldane method of indirect calorimetry, following the directions given by Cathcart;⁵ in this

method, which is recognized to be an accurate one, both O_2 and CO_2 are estimated in the expired air.

The children under observation were of an age—8 to 16 years—of understanding, and met the conditions of experiment willingly. After a few preliminary trials with the mouthpiece, the process of taking a sample of expired air concerned them little. One factor which helped us considerably was that our subjects, being hip or spine cases, were fixed in splints in bed. Movement, except of the head and arms, was practically impossible. We took care to exclude movement of the head and arms for the usual period before taking the sample.

Breakfast was taken at 6 a.m., a glass of milk at 8.30 a.m., dinner at 12 noon, tea at 4 p.m., and supper at 7 p.m. (summer time). In the case of observations made before breakfast, breakfast was taken at 8.30 a.m. Observations after breakfast were made between 10 a.m. and 12 noon; those after dinner between 2 p.m. and 4 p.m.

Records of dry and wet bulb air temperatures, of dry and wet kata-thermometer cooling powers, and of black fur surface temperatures were taken to give indications of the atmospheric conditions under which the observations were made. The last give a measure of the radiant energy of the sun. Records of cheek surface and axillary body temperatures and of pulse rates were also taken. We did not employ subjects who showed an abnormal body temperature. Only one or two of our cases showed a broken skin, and these lesions were sinuses or ulcers of a minor degree.

For comparison, we have used the figures for calories per diem given in Benedict and Talbot's⁶ standards for children of the same weight as ours; these are well known basal standards. Strictly speaking, the only figures of our results that may be compared with these basal standards are those we obtained from our subjects in the post-absorptive state—that is, before breakfast. Nevertheless for comparing one set of our figures with another set of our figures obtained under similar conditions in regard to the taking of food, we have taken the liberty of using these standards, and noted what difference each set of our results showed from the standard for children of the same weight as ours. This seemed to be the best method for comparing our results. We have also calculated the heat production per unit of body surface, using both Du Bois's and Benedict and Talbot's formulae for calculating the surface and reaching the same conclusions from the use of each.

Results obtained from Children who had been Treated for many Months with Open Air and Heliotherapy.

Our first experiments were done on children who had been under treatment for many months. Some of them had pigmented very well under the influence of the sun—that is, to say, they had not blistered, but bronzed. Others, who did not pigment well, easily blistered, and, not tolerating much exposure to sun, were kept more in the shade. All the children on an ordinary summer's day wore only loin-slips, and paid no attention to the fact that they were so much exposed to the open air; there was no evidence of shivering.

Sir Henry Gauvain states that the children who do not pigment well are slower in progress. We noted that the children who pigmented well were usually of better weight than those who did not pigment well, but the average difference in metabolism at Alton was negligible after due allowance was made for difference in weight. From this we conclude that heliotherapy was not so much responsible for the rise in metabolism observed as was the open air, since those who pigmented well received much more heliotherapy than those who did not pigment well.

We should like to emphasize here that we were not dealing with the cure of the disease but with the metabolism alone. While many clinicians hold the view that heliotherapy is greatly concerned with the arrest of the disease, the different factors at work have not so far been analysed.

To return to our results: Table I shows the figures obtained from those who pigmented well, and Table II shows the figures from those who did not pigment well. The Alton figures may be compared. Taking both Table I and Table II together the average increase of our figures before breakfast above the standard figures for the same weight was about 40 per cent., whereas after breakfast and after dinner the average increase over the standard was about 50 per cent. The out-of-door cooling power and its effect on metabolism vary, but we may conclude that the average effect of the hospital food in our observations was not more than 10 per cent. Du Bois found the basal metabolism increased only

TABLE I.—Average Figures for Children who Pigmented Well.

Time and Place.	Age (Years).	Weight in Kilos.		No. of Observations.	Calories per diem†		Percentage Increase of Calories over Standard.
		Found.	Standard*		Found.	Standard†	
Before breakfast.							
At Alton ...	11.5	32.0	32.0	7	1598	1172	36.3
At Hayling ...	12.0	29.9	35.0	12	1555	1067	45.7
After breakfast.							
At Alton ...	12.0	27.6	35.0	9	1579	1046	50.9
At Hayling ...	11.0	25.4	30.0	19	1464	974	50.3
After dinner.							
At Alton ...	11.3	37.2	31.0	9	1852	1302	42.2
At Hayling ...	11.7	30.9	34.0	21	1670	1108	50.7

* For same age.

† The resting metabolism found during exposure out of doors is calculated per diem. The metabolism is at a lower figure when the child is clothed and in the ward during the night.

‡ For same weight without food.

2 per cent. by a light breakfast (two to three hours after it). We consider that the 40 per cent. increase of our figures above the standard was due to increase of bodily tone by exposure to open air. We have already proved that metabolism of healthy adults wearing ordinary clothes is raised sometimes nearly 40 per cent. by open air apart from heliotherapy.¹

TABLE II.—Average Figures for Children who did not Pigment Well.

Place and Time.	Age (Years).	Weight in Kilos.		No. of Observations.	Calories per diem.		Percentage Increase of Calories over Standard.
		Found.	Standard.		Found.	Standard.	
At Alton.							
Before breakfast	10.3	23.4	27.0	9	1345	948	41.8
After breakfast...	11.7	26.3	33.0	10	1431	1017	40.7
After dinner ...	13.0	29.4	40.0	10	1636	1094	49.5

Some may think that the better conditions of diet, etc., provided in hospital were partly responsible for the increase in the case of these children, but we take it that they were not much better than the conditions for the healthy children from whom Benedict and Talbot obtained their standards. It is not merely a question of provision of food, but of stimulus, by open air exposure, to eat and absorb the food. Other points of argument will be considered in our next experiment.

Results obtained from Children "On Admission" and After the First Three Months of Open Air and Heliotherapy.

Sixteen children, eight boys and eight girls, were employed for observations a few days after admission and again after the first three months of open air and heliotherapy. The girls were above, but the boys were under, normal weight for the same age.

These children were placed in isolation cubicles, which were very well ventilated, the cooling power in these cubicles being much the same as in the shade outside. The children were in bed covered with light bedclothes. As a rule the upper part of the body was covered only by a thin shirt. There seems little doubt that most of them had been much more shut up in their own homes.

As a rule we took four observations on consecutive days from each child whilst in the cubicle a few days after admission, so that they would be accustomed to their new surroundings. After two weeks in the cubicles the children were taken outside in bed and gradually exposed to the open air and sun. Some of them were more able to stand exposure than others at the end of three months' treatment, so that the former were more pigmented than the latter. In any case none of these children were so well adapted to exposure as the children who had been in hospital for some months longer.

Table III shows the average results we obtained "on admission" and "after the first three months of treatment." It will be noted that "on admission" our figures were about 30 per cent. above the standard, and "after three months of treatment" they were about 50 per cent. above the standard, so that there was a 20 per cent. increase in metabolism. These observations were taken after breakfast and after dinner, but we were careful in each case to take the observations "after three months' treatment" at the same time, with regard to meals, as our observations "on admission."

We have already shown that on an average the hospital diet is responsible for an increase in metabolism of 10 per cent., so that our figures become for "on admission" 20 per cent. above the standard, and for "after three months' treatment" 40 per cent. above the standard. We have made full allowance for the children's increase in weight owing to their condition improving, in the hospital, by taking, for comparison, the standards for the different weights of each child observed "on admission" and "after three months' treatment."

TABLE III.—Average Figures showing Effect on Metabolism of Three Months' Treatment.

	Eight Boys, aged 10.4 Years.	Eight Girls, aged 9.5 Years.
Weight in kilos:		
On admission ...	22.3	25.8
After three months' treatment ...	24.3	27.0
Standard for same age ...	27.0	24.0
Number of observations:		
On admission ...	29	37
After three months' treatment ...	30	28
Calories per diem:		
On admission, with food ...	1183	1270
After three months' treatment, with food ...	1460	1514
Standard, for same weight on admission, without food ...	916	946
Standard, for same weight after three months' treatment, without food ...	973	975
Percentage increase of calories found over standard:		
On admission ...	29.1	34.2
After three months' treatment ...	50.2	55.3
Percentage increase in metabolism after three months' treatment	21.1	21.1

It seems at first sight a remarkable result that the children examined in the cubicles "on admission" had a metabolism on an average 20 per cent. above the basal standard. The observations numbered 96 for 22 children. Recently Blunt and others,² using an indirect method of calorimetry, and therefore not a closed chamber, found that the basal metabolism of under-weight children tends to be higher than that of the normal child. In some of our cases this may be the explanation, but many of our children were not under-weight, and those who were under-weight did not by any means give the highest percentage increments. Wright,³ using the same method as we did, has published some figures which indicate that the metabolism of healthy British naval youths in bed and in hammocks is much higher than the basal standards for children in closed chambers. The increase is probably due to the different conditions of atmosphere and clothing under which our observations and the basal standards were obtained.

As already stated, our observations "on admission" were taken in especially well ventilated cubicles, whereas Benedict and Talbot's standards were obtained whilst the child was in a closed chamber. Undoubtedly under our conditions more "tone" would be retained than under Benedict and Talbot's conditions. The temperature inside their chamber was not far from 22° C. to 23° C. The authors⁴ advise that the subject in this chamber should be dressed, including stockings and shoes; in addition a pair of woollen socks should be drawn over the shoes to prevent cold feet. In the cubicles at Alton we observed an average dry bulb temperature of 19.9° C., the figures ranging from 17.4° C. to 22.6° C. We

have shown^{1, 2} that body metabolism is not regulated by temperature of the air, but by cooling power—that is, the wind and other factors are concerned as well as the dry bulb temperature.

We must take into account the presence of muscular spasm in some of our cases owing to the disease, but these worst cases did not give the highest figures; and Wright's naval cadets were obviously not ill. We see no reason to assign any great part to psychical influence, since our subjects were isolated and were accustomed to their new surroundings before we made our observations.

It is possible that English children have a somewhat higher basal metabolism. We do not know of any observations that have been done on children of this age in this country in chambers similar to those used by Benedict and Talbot.

Note on Balneotherapy.

In Table I it will be observed that we have given separate figures for Alton and Hayling Island. The Hayling Island percentages are, on the whole, higher than those for Alton. At Hayling Island the children lived in a more exposed position, and had balneotherapy in the sea in addition to open-air treatment and heliotherapy. The period of immersion in the sea varied between half a minute and seven minutes per day during the summer, with a sea temperature of about 60° F.* We took samples of expired air for analysis during the immersion, and found that metabolism was between two and three times that of resting metabolism, and, of course, higher if movement—swimming, etc.—were allowed. Sir Henry Gauvain states that some children do better under the seaside conditions at Hayling Island than inland at Alton; others do better at Alton than at Hayling Island; others, again, do better if given an occasional change from one place to the other.

In conclusion, we wish to state that the excellent muscular tone and condition of the children who had been treated is sufficient evidence of the high value of the methods employed, and is remarkable when one considers that the children had been fixed in splints in bed for so long a time. It seems likely that this carefully graduated treatment could be applied with success in other conditions involving a long period in bed.

We are indebted to the members of the hospital staffs for much help during this work.

Summary.

1. Observations during the past summer on metabolism of children crippled with surgical tuberculosis and lying fixed in splints in bed and more or less nude, at Lord Mayor Treloar's Hospital, Hampshire, are described. Their metabolism on the average was increased 40 per cent. above the standard, for the same weight, of children confined in a closed calorimeter.

2. After three months' treatment, including graduated exposure to open air and heliotherapy, their metabolism out of doors was 20 per cent. above that in well-ventilated cubicles soon after admission.

3. Children who had been treated for many months showed high metabolism in the out-of-door conditions, those who pigmented well in the sun giving about the same figures as those who did not pigment well, after making allowance for weight. The former gave the better figures for weight.

4. It is considered that the rise in metabolism caused by heliotherapy *per se* is insignificant compared with that caused by exposure to open air. At the same time the value of heliotherapy as a factor towards arrest of the disease is not disputed.

5. Children on admission in well-ventilated cubicles gave results about 20 per cent. higher than basal standards for closed calorimeters. It is considered that the open-air conditions in the former were mainly responsible.

6. Balneotherapy increases metabolism much above the resting level.

7. The bodily tone and general condition of the children under the specially graduated treatment is remarkable when the long period of immobilization in splints in bed is considered. The treatment might be applied with advantage in other cases involving long confinement in bed.

* Varying periods of immersion result in corresponding variations in metabolic activity. Balneotherapy thus affords a ready and controllable means of stimulating metabolism to a desired degree. We are not concerned in this paper to discuss the optimum metabolism desirable, though we cannot fail to appreciate the clinical importance of this factor in treatment.

APPENDIX.

A number of experiments were completed during the past few winter months. On suitable days the children were placed out of doors in the sun, even though the temperature of the air was very low. They were covered up with bed-clothes, only the face and hands being exposed. The days were few on which the children had to be kept indoors during our observations. The table shows the results obtained, the figures being given as percentage increments over the standard basal figures for the same weight. The observations were made about five hours after breakfast and three hours after a glass of milk, so that no more than 10 per cent. should be deducted throughout for the influence of food.

Table showing Percentages above Basal Figures.

	Subject.					
	H.Z.	J.L.	A.H.	H.N.	E.G.*	J.C.*
In Summer, under ordinary conditions of open-air treatment	37	52	46	60	69	32
In Winter:						
Under ordinary conditions of open-air treatment	58	59	73	96	99	79
In warm room at 70° F. ...	—	50	51	78	62	27

* E. G. and J. C. were kept in the warm room at 70° F. for four days and four nights, and for some observations were in the post-absorptive state.

It will be observed that the winter results are, on the whole, a good deal higher than those obtained for last summer. Apart from this general statement, the winter results are not comparable with one another, since some were taken on much colder days than others, as indicated by the cooling power of the atmosphere.

We also imitated Benedict and Talbot's conditions by placing the subjects in a warm room at about 70° F. The results in the warm room should be compared with the winter results under ordinary conditions of treatment, as the former were, as a rule, obtained a couple of hours after the latter. The metabolism was decreased—in some cases markedly—by this process, but on the whole it was still much above the basal standard. We do not think that the disease in itself can explain much, if any, of the difference, but think it probable that the children, owing to open-air treatment, had a higher basal metabolism than those from whom the basal standards were obtained in America, and that only prolonged warm room treatment will bring it down. The Britisher going to the tropics has, at any rate for some time, a higher basal metabolism than the native during waking hours.

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THE members of the City Medical Society of Kankakee, Illinois, U.S.A., have been discharging since March, 1921, the duties usually performed by the county and township medical officer with regard to necessitous persons, and recently also those of the medical officer of health for the city. The members of the society are divided into four groups, each of which serves for three months. In each group are practitioners who are competent to do major surgery, as well as specialists in eye, ear, nose, and throat work. The scheme provides that the indigent shall have a choice of medical practitioner, and, according to the *Journal of the American Medical Association*, the service is more competent than could be rendered by an individual medical man; the expense to the community is no greater. The fee the society receives for this work is devoted to maintaining headquarters for the organization and a library, and any surplus which may accrue will be used to provide greater facilities and equipment for all medical practitioners who are members of the organization.