fed rats. The spleens of rats with lower calcium intakes showed a weight gain during gestation which disappeared during the subsequent lactation.

7. Fertility of the dam and mothering instinct were not impaired, even in severe calcium deficiency. The weight of the young at birth and the number of young in a litter were not affected by the level of calcium intake by the dam. Weaning weights of young from severely deficient dams were lower.

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A Balance Sheet of the Estimation of Energy Intake and Energy Expenditure as Measured by Indirect Calorimetry, Using the Kofranyi-Michaelis Calorimeter

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(Received 30 July 1951)

In a recent review, an expert committee of the Food and Agricultural Organization of the United Nations (1950) sets out existing physiological knowledge of energy requirements from food in relation to practical rationing problems. Throughout their report the committee again and again draw attention to the gaps in present knowledge and to the need for further investigations. One method of assessing food requirements is the measurement of energy expended (in terms of heat loss) during various physical activities. Direct measurements of the heat loss of man under varying conditions have been made. Such methods of direct calorimetry possess the advantage of great accuracy, but human calorimeters are expensive and require great skill in use. Though they are invaluable as instruments for determining basic physiological principles, they can be of little help in tackling problems of energy requirements under conditions of everyday life. Indirect calorimetry (the assessment of energy expenditure from measurements of rates of oxygen consumption) is a more practical possibility but, even by these means, the drawing up of an energy balance-sheet presents great difficulties.

The metabolic cost of numerous activities has been accurately determined by measurement and analysis of samples of expired air collected in Douglas bags. The size and clumsiness of these bags limit their range of use in everyday life; their small capacity in relation to lung-ventilation rates limits the time for which one bag can be used. For these reasons estimations of the cost of complicated activities, such as take place in modern industry, are always difficult and time consuming, so much so as to be often wellnigh impossible. Many attempts to draw up a daily cost of energy expenditure by persons of different occupations have been made; these have been reviewed and summarized by Orr & Leitch (1937–8). Such estimates, though probably essentially correct, depend of necessity on much guess-work and have a wide range of error.

The development by Kofranyi & Michaelis (1940) of a compact, light, portable calorimeter is a great technical advance. This instrument is essentially a dry gas-meter, weighing only 4 kg and easily carried on the subject's back; it measures directly the volume of the expired air, and at the same time collects a continuous sample of a small constant fraction, which is available for subsequent analysis. The calorimeter has already been used in Germany for a big survey of energy expenditure in industry (Lehmann, Müller & Spitzer, 1949–50), and for a detailed study of the metabolic cost of the housewife's manifold activities (Droese, Kofranyi, Kraut & Wildeman, 1949–50). Similar studies have not been made in industry in this country.

In this laboratory Orsini & Passmore (1951) have compared results of the cost of a range of simple standardized work, using both Douglas bags and the Kofranyi-Michaelis calorimeter and found a good agreement between the two. But before undertaking a survey of the energy cost of various activities in British industries, we thought fit to test the instrument and the reliability of methods of indirect calorimetry in a laboratory study. The plan was that the subjects of the experiments should live in the laboratory for a period, during which a complete record of activities would be made, and the cost of sample activities determined by means of the calorimeter. In this way estimates of total energy expenditure could be obtained. At the same time accurate measurements of food intake would be made, and an assessment of the total calories available for expenditure provided. If a reasonable agreement were found between these two estimates, this would provide a measure of the reliability of the methods, and might provide a basis of confidence for results obtained later in industry under conditions less suitable for prolonged observations.

METHODS

General. Five students, men between 19 and 25 years, acted as subjects and lived in the Department for 2 weeks. During 13 consecutive days, a detailed time record was kept of all their activities, all food consumed was weighed and the metabolic cost of about thirty separate activities determined for each subject. The plan was to spend the first 3 days in sedentary life within doors, then to have 5 days of hard physical work, and finally a second period of 5 days of sedentary life. The two sedentary periods passed according to plan. The subjects spent the whole time in light activities and undertook no hard work. Except on two or three occasions when they went on small errands, they did not leave the building.

For the hard physical activity, outdoor track-walking was chosen. This is hard work, a steady and continuous activity, whose metabolic cost can easily be determined. The movements involved are those to which the subjects were of necessity accustomed in their everyday life. Unfortunately, the weather proved unkind, and wind and rain made conditions variable and often unfriendly on the grass track 1030 yd. around the University athletic ground. On one afternoon conditions were so bad that climbing up and down stairs in the laboratory was substituted for walking. Unfortunately three of the subjects developed blisters and minor orthopaedic trouble which on occasions restricted activity. Further, John, one of the fittest, developed mumps in the middle of the experiment and was only available for heavy work on 3 days, during which he walked 50 miles. Evan, whose feet prevented his exercising on one day, walked 52 miles. Iain, George and Alistair walked 66, 71 and 76 miles respectively, spread out over the 5-day period. The speed of walking varied between 4·2 and 4·8 m.p.h. In addition to the walking, a dance was held at the end of the work period. The metabolic cost of the various dances was determined without difficulty. One subject, George, played two games of Rugby football. The direct cost of these games could not be measured, but an estimate was made by comparison with other activities.

Choice of diet and estimation of its energy value. Because of uncertainties about the accuracy of estimates from food tables it was decided that the energy value of the diets should be obtained by chemical analysis of duplicate samples. To allow each subject to choose the whole of his diet quantitatively and qualitatively was impractical because of the very large number of analyses which such a procedure would have involved. Thus, to reduce the number as far as possible, about half of the total energy value of the diet each day was provided as a basic diet which was exactly the same for each subject. For the remainder of the diet each man was allowed to eat as much as he liked of bread, butter, sugar, bramble jelly, processed cheese and milk. Beer or cider was available at the evening meal. All these, as well as a sample of the basic diet for each day, were analysed separately. The energy values were calculated from the chemical analysis for moisture, protein, fat and ash. Carbohydrate was obtained 'by difference' and the energy value estimated from the carbohydrate, fat and protein content using the Atwater factors, 4, 9, 4.

The eating habits of the men had been observed during a preliminary study, and the pattern of the meals during the 13 experimental days was as close to this as possible.

The selection of dishes was in agreement with the likes and dislikes of the subjects. The pattern of the daily diet was as follows:

Breakfast: porridge or cereal and fruit juice; cooked dish.

Lunch: meat, fish, cheese or egg dish; potato and other cooked vegetable; baked or steamed pudding; biscuits.

Tea: cake or biscuit.

Dinner: meat, fish, cheese or egg dish; potato and other cooked vegetable or salad; hot or cold dessert, e.g. trifle, fruit pie.

At each meal weighed quantities of bread, butter, cheese, sugar, bramble jelly and milk were placed before each subject so that he could eat as much as he desired of any of these six foods. The amount eaten by each was ascertained by weighing what was left at the end of the meal. All foods were placed in covered vessels to avoid loss of weight by evaporation. Cellophane bags were found to be ideal for the bread. Either coffee or tea was served with each meal. No allowance was made for the energy value in either tea or coffee.

Using this technique it was possible to present a varied menu each day and also to limit the number of chemical analyses to about twenty samples for the whole period. Care was taken to avoid the use of foods difficult to sample, e.g. very fat meat or bacon, and for the same reason, frying as a method of cooking was avoided. Composite dishes, such as fruit pies, meat cooked with vegetables as in stews, trifles and salads, were prepared by weighing each ingredient for each subject and also for the sample for analysis. Where cooked, these were weighed and served in individual Pyrex dishes. This technique proved to be acceptable to the subjects, and, as none left any of the basic diet on his plate, was equally successful from our point of view.

One subject, John, did not consume the basic diet for 5 days while he was suffering from mumps. Weight records of each item eaten were kept and, during that period, the estimate of the energy value of his diet was made from food tables. While ill he consumed mostly milk, sugar, eggs, fruit juices, bread and butter. The energy value of these particular foods is fairly definite and the error introduced from this method of calculation should be very small.

Indirect calorimetry. Basal metabolic rates, and rates lying at rest, were determined with a Benedict-Roth spirometer, assuming a respiratory quotient of 0·78. All other rates were obtained using the Kofranyi-Michaelis calorimeter. Gas analyses were carried out in duplicate using the Haldane apparatus. All estimates covered periods of at least 6 and at most 15 min, the average being 10 min. As conditions varied owing to the weather on the outdoor track, estimations on each subject were made each morning and afternoon when walking was undertaken. Speeds varied slightly in the different periods. For each subject the range of cost for sitting activities was small, and for light indoor activities not great. Accordingly, selected values have been chosen for sitting activities and for light indoor activities. These have been used throughout. To split up these two groups into their separate activities would have involved an immense labour and, in the conditions of our experiment, would probably add little to the accuracy.

Record of activities. The problem of recording, from minute to minute and from day to day for 13 days, the multifarious activities of five active young men seemed, on first consideration, to demand the assistance of five observers. Under other conditions, with less intelligent or less enthusiastically co-operative subjects this is probably so. In the present investigation, however, each subject acted as his own observer, timing and recording his activities in great detail on a specially designed activity chart. Each chart, foolscap size, covered 8 h of the day, providing a 3 in. square for each hour. The hour squares were subdivided into sixty smaller squares for recording by minutes and a small compartment for notes on the activities engaged in during the hour. The minute squares were quickly filled in with red or blue pencil, a change of colour indicating a change of activity. Code letters of the various activities indicated the meaning of each change of colour from blue to red or red to blue. These code letters were explained in a legend at the bottom of the chart, but it was possible for the subject to record any doubtful or undefined activity by an additional code letter, the meaning of which was then added to the legend. Two 8 h charts recorded the details of each waking day and from them it was possible to calculate the total time spent daily on each of the various activities recorded. To guard against possible forgetfulness or inaccuracy when out of the Department, each subject had a notebook in which details and time were noted for later transcription to the chart.

RESULTS

Metabolic cost of various activities. Table 1 shows the results of all the estimations of metabolic cost during the 13 days, except those obtained on John when febrile, which are shown separately in Table 2. Tables 3–7 record, for each subject for the total period of 13 days, the total time spent in each classified activity, the estimated cost of the activity and the total calories expended. The activities are arranged according to the total calorie expenditure over the period. The justification for grouping all sitting activities together and all light indoor activities together has already been explained. The total period spent in bed each night, from the time of lying down until rising in the morning, was costed at the basal metabolic rate on the assumption that any period when the metabolic rate was above the basal rate would approximately balance the period during sleep when calorie expenditure might be expected to fall a little below the basal rate. Any other period during the day which was spent lying down was recorded under the heading 'lying at rest'.

'Indoor walking' was assumed, from careful observation, to be carried out at approximately 3 m.p.h., except by George, who generally moved somewhat faster than the others.

'Stair climbing' covers the routine daily movements about the building carried out as nearly as possible at 100 stairs/min whether climbing or descending. 'Stair exercise', on the other hand, covers a period of carefully timed and controlled exercise which replaced 'track walking' on a particularly inclement afternoon. The apparently large amount of time spent in climbing stairs is due to the subjects having to live and sleep at the top and feed on the ground floor of a building not provided with a passenger lift.

Energy balance of the subjects. Table 8 shows the energy value of the food consumed and Table 9 the final balance for each subject. For John, George and Evan, who each gained a little weight up to 0·34 kg, the estimated energy value of the food absorbed is up to 2100 Cal. above the estimated expenditure. This represents an average daily difference of less than 160 Cal. or up to 5 % of the total. Alistair was estimated to have used 5000 Cal. less, and Iain 3100 Cal. more, than he ate. But for Alistair, against the excess of food, there is the 2·66 kg gain of weight; against Iain's food deficit a loss of 2·49 kg of body-weight can be set. Any attempt to convert

Table 1. *Metabolic cost of various activities (in Cal./min)*

Activity	John (67 in., 131 lb.)	George (68 in., 152 lb.)	Alistair (72 in., 166 lb.)	Evan (72¾ in., 175 lb.)	Iain (75 in., 183 lb.)
Basal	1·12, 1·13, 1·11	1·20, 1·15, 1·26	1·14, 1·09, 1·21	1·31, 1·16, 1·27	1·22, 1·27, 1·20
Lying at ease	1·4, 1·4, 1·2, 1·4	1·4, 1·6, 1·4	1·4, 1·6, 1·5	1·5, 1·6, 1·6	1·5, 1·4, 1·3
Sitting:					
At ease	1·5	1·9	1·8	1·9	2·0
Calculating	1·5, 1·2, 1·7	2·3	2·0	2·0	2·1
Reading	—	2·2	1·9	—	—
Writing a letter	—	1·9	2·2	2·0	2·2
Listening to the Boat Race	—	—	—	2·0	2·5
Playing Canasta	2·0	2·1	2·1	1·9	2·5
Unspecified (selected value)	1·8	2·2	2·1	2·0	2·3
Standing at ease	1·5	2·2, 2·1	2·0, 2·3	2·5, 2·4	1·8, 1·9
Light indoor activities:					
Peeling potatoes	—	2·7	—	—	—
Washing dishes	—	—	3·7	3·4	3·9
Washing socks	—	4·1	—	—	—
Cleaning shoes	—	—	—	3·3	4·7
Laboratory work	2·5	3·5	3·9	3·9	3·3
Dressing, washing, shaving	2·8	4·1	3·6, 3·7	4·5, 4·1	3·9, 4·2
Making beds	—	—	7·6	—	—
Unspecified (selected value)	2·7	4·0	3·8	4·0	4·0
Walking:					
Indoors 2·4 m.p.h.	4·3	4·7	3·8	—	5·1
3·0	—	5·6	5·5	5·3, 5·4	5·1, 5·9
Outdoors 4·0	—	8·2	—	—	—
4·2	8·2	9·0	—	10·4, 11·3	9·8
4·4	9·1	10·3, 9·5, 10·1	9·7, 9·8, 9·9	10·7	—
4·6	10·1	—	10·6	—	11·0, 11·2
4·8	10·2	10·6	12·0	11·6	11·2, 13·7
Up and down stairs 97 per min	6·6	8·0, 8·9	9·6, 10·1	9·9, 9·5	9·6, 9·3, 9·0
116	8·5	8·4	10·3	10·4	11·8
Dancing:					
Foxtrot	—	—	—	5·2, 5·2	5·8
Waltz	—	—	5·7	—	7·1
Rumba	—	7·0	—	—	—
Petronella	—	4·7	—	—	—
Eightsome reel	—	7·5	—	8·1	7·5

Table 2. *Energy expenditure of John, lying in bed febrile*

Temperature (° F)	Cal./min
99·6	1·31
101·0	1·34, 1·44
101·6	1·54

these weight changes into corresponding calories could only be the wildest guess in the absence of precise measurements of changes in body-water content.

During the first 3 days of sedentary life, all the subjects consumed more than they expended. The excess appetite was no doubt partly psychological and could be

Table 3. *Energy expenditure of John over 13 days*

Activity	Time h	Time min	Energy expenditure Cal./min	Energy expenditure Total Cal.
Track walking	11	8	9·2	6,170
In bed	56	14	1·11	3,750
Light sedentary activities	27	0	1·8	2,920
Sitting at ease	28	38	1·5	2,580
Walking (about 3 m.p.h.)	4	52	5·0	1,460
Light standing activities	6	21	2·7	1,030
Stair exercises	1	54	8·5	970
Dressing, shaving	3	59	2·8	670
Stair climbing	1	1	7·0	430
Lying at rest	1	37	1·4	140
Sundry activities	1	55	—	180
Total	6 days			20,300
Sitting up in bed	69	57	1·6	6,720
Lying in bed (febrile)	44	29	1·35	3,600
Lying in bed (afebrile)	41	58	1·11	2,800
Lying in bed (afebrile) (low fever)	11	28	1·25	860
Out of bed	—	8	4·0	30
Total	7 days			14,010
Grand total	13 days			34,310

Table 4. *Energy expenditure of George over 13 days*

Activity	Time h	Time min	Energy expenditure Cal./min	Energy expenditure Total Cal.
Light sedentary activities	111	19	2·2	14,690
Track walking	15	53	9·4	8,910
In bed	112	58	1·2	8,130
Walking (about 3·5 m.p.h.)	18	11	6·5	7,090
Light standing activities	13	57	4·0	3,350
Dressing, shaving	9	5	4·1	2,235
Lying reading, etc.	18	28	2·0	2,220
Rugby football	2	54	10·0	1,740
Stair climbing	2	22	8·5	1,210
Dancing	2	8	—	800
Stair exercise	1	24	8·4	710
Standing at ease	3	20	2·1	420
Total	13 days			51,510

Table 5. *Energy expenditure of Alistair over 13 days*

Activity	Time h	Time min	Energy expenditure Cal./min	Energy expenditure Total Cal.
Light sedentary activities	103	46	2·1	13,070
Track walking	17	14	10·1	10,390
In bed	118	16	1·15	8,160
Walking (about 3 m.p.h.)	12	46	5·5	4,080
Light standing activities	14	41	3·8	3,350
Lying at rest	24	49	1·5	2,230
Dressing, shaving	5	49	3·7	1,290
Stair climbing	1	44	9·8	1,020
Sitting at ease	8	54	1·8	960
Stair exercise	1	21	10·3	870
Sundry activities	2	40	—	560
Total	13 days			45,980

Table 6. *Energy expenditure of Evan over* 13 *days*

Activity	Time h	Time min	Energy expenditure Cal./min	Energy expenditure Total Cal.
Light sedentary activities	90	31	2·0	10,860
Track walking	11	48	10·7	7,580
In bed	121	13	1·2	8,730
Light standing activities	24	7	4·0	5,790
Walking (about 3 m.p.h.)	6	33	5·3	3,990
Lying at rest	36	25	1·6	3,500
Dressing, shaving	7	32	4·3	1,940
Stair climbing	2	44	10·0	1,640
Dancing	2	14	—	910
Stair exercise	—	51	10·4	590
Sundry activities	2	1	—	470
Total	13 days			46,000

Table 7. *Energy expenditure of Iain over* 13 *days*

Activity	Time h	Time min	Energy expenditure Cal./min	Energy expenditure Total Cal.
Light sedentary activities	126	18	2·3	17,430
Track walking	15	8	10·3	10,100
In bed	117	0	1·2	8,420
Light standing activities	15	28	4·0	3,710
Dressing, shaving	13	43	4·0	3,290
Walking (about 3 m.p.h.)	6	2	5·5	2,000
Stair climbing	2	15	9·3	1,260
Stair exercise	1	29	11·8	990
Dancing	2	14	—	900
Sitting at ease	7	29	2·0	900
Sundry activities	4	54	—	580
Total	13 days			49,580

Table 8. *Energy value of diets* (*Cal.*)

First sedentary period	John	George	Alistair	Evan	Iain
Day 1	2,920	3,140	2,900	2,960	3,050
2	3,300	3,690	3,430	3,580	3,370
3	3,650	4,010	3,540	3,510	3,480
Mean	3,290	3,610	3,290	3,350	3,300
Action period					
Day 4	4,270	4,330	4,530	4,240	4,020
5	3,660	4,040	4,360	3,580	3,670
6	3,540	4,340	4,360	3,560*	3,740
7	1,080†	4,050	3,630	3,320	3,250
8	990†	4,010‡	4,090	3,730	4,430
Mean	3,820§	4,150	4,190	3,690	3,820
Second sedentary period					
Day 9	1,410†	4,370	3,500	4,260	4,040
10	1,800†	4,530‡	3,840	4,150	3,420
11	3,220†	4,480	4,250	3,490	3,520
12	3,550†	4,260	4,450	4,050	3,250
13	2,890†	3,840	4,140	3,700	3,060
Mean	2,576	4,300	4,040	3,930	3,460
Grand total (13 days)	36,280	53,090	51,020	48,130	46,300

* Sedentary. † In bed—mumps. ‡ One game Rugby football. § Average of 3 days only.

Table 9. *Total estimated energy expenditure of the five subjects over* 13 *consecutive days compared with energy value of the diet for the same period*

	John	George	Alistair	Evan	Iain
Estimated energy expenditure Cal.)	34,310	51,510	45,980	46,000	49,580
Energy value of diet (Cal.)	36,280	53,090	51,020	48,130	46,300
Weight changes (kg)	+0·34	+0·31	+2·66	+0·14	−2·49

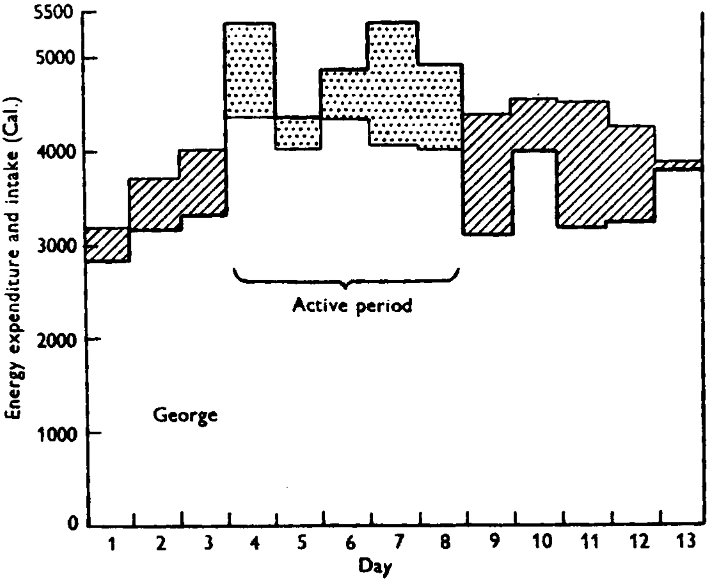

Fig. 1. Energy balance for George. Thin line, daily energy intake; thick line, daily energy expenditure. Cross-hatched areas show excess intake over expenditure; stippled areas show excess expenditure over intake.

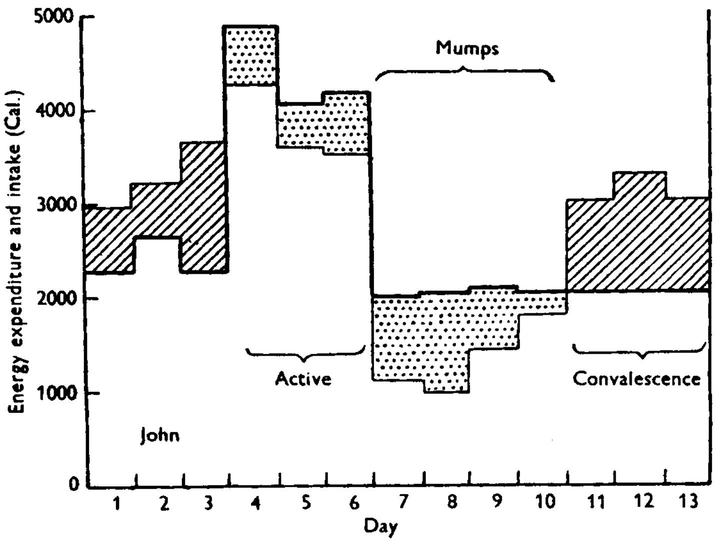

Fig. 2. Energy balance for John. Thin line, daily energy intake, thick line, daily energy expenditure. Cross-hatched areas show excess intake over expenditure, stippled areas show excess expenditure over intake.

explained to some extent by natural relaxation at the end of term, and also perhaps as a compliment to our cook. During the 5-day exercise period, when expenditure rose as high as 6000 Cal., intakes also rose, but never to the level of output. This may be explained by simple physical fatigue. The men were just too tired to eat. The deficit was made good during the second 5-day sedentary period, when all ate each day food with an energy content a little greater than the energy expended. Fig. 1 shows the day-to-day variations in intake and expenditure for George. Alistair, Evan and Iain all showed essentially the same pattern. John also followed the same course until mumps developed on the 7th day. Thereafter, till the end of the experiment, he stayed in bed with a daily expenditure remaining constantly around 2000 Cal. For the first 2 days the fever and the pain restricted food intake to about 1000 Cal., but, on the final 3 days, when convalescence was fully established, he made up the deficits with intakes of the order of 3000 Cal. Fig. 2 shows his two periods of negative balance (exercise and acute illness) and his two periods of positive balance (good appetite and convalescence). By a happy chance these two pairs equalled each other, the weight lost in the illness was regained and over the 13 days a good balance was obtained.

Table 10. *Average energy expenditure (Cal.) of the five subjects during sedentary and active periods compared with recommended allowances*

	John	George	Alistair	Evan	Iain
			Average energy expenditure		
Sedentary period	2400	3240	2870	3040	3080
Active period	4350	4950	4610	4650	5040
			Recommended allowances (Food and Agriculture Organization of the United Nations, 1950)		
Activity: Moderate	3019	3378	3553	3725	3825
			(Canadian Council on Nutrition, 1950)		
Sedentary	2225	2425	2575	2675	2750
Moderate	2750	2950	3100	3200	3275
Heavy	3500	3700	3850	3950	4025
Very heavy	4500	4700	4850	4950	5025

Energy expenditure and reference standards. Table 10 shows the average expenditure of the five subjects during the sedentary and active periods set out in relation to two well-known reference standards. Allowances have been made for the age and weight according to the recommendations laid down by the Food and Agriculture Organization of the United Nations (1950) and the Canadian Council on Nutrition (1950).

It will be seen that, during the sedentary period, the energy expenditure for four of our subjects was between 600 and 900 Cal./day less than the F.A.O. recommendations. Our fifth subject, George, was, however, expending only 150 Cal./day less during the sedentary period than the F.A.O. recommendation based on moderate activity. As has been explained earlier, George normally moved more quickly than the others. During the period of great physical activity the subjects expended between 900 and 1600 Cal./day in excess of the F.A.O. estimate.

Except for George, the energy expenditure during the sedentary period lay between the allowances recommended for sedentary occupation and moderate activity on the

Canadian standard. During the period of great physical activity the energy expenditure of all subjects was within 300 Cal. of that estimated by the Canadian Council on Nutrition for very heavy workers.

DISCUSSION

For practical reasons it was unfortunately not possible to carry on this experiment for longer than 13 days. The inclusion of a water-balance study would have been of considerable value in the interpretation of these results, but was too complicated to include in the programme; over the short period there were differences in the initial and final body-weights, but it is impossible to estimate how far these differences represent changes in body tissue.

Two subjects showed considerable weight changes; Iain lost 2·49 kg and Alistair gained 2·66 kg. The others all gained weight, but less than 0·34 kg. The differences between the energy value of the food eaten and the energy expended were in agreement with these weight changes, being −3300 Cal. for Iain, +5000 Cal. for Alistair and between +1500 and +2100 Cal. for the others. When the experiment had to be terminated at the end of the 13th day, John, Alistair and Evan were still eating in excess of their estimated daily energy expenditure, even after having made up the deficit caused by the very high expenditure between the 4th and 8th days, although it was evident that the excess of intake over output was decreasing fairly rapidly. George, on the other hand, appeared to have reached a balance on the 13th day and it might reasonably have been expected that the others would have done likewise within a comparatively short time. Iain too, was at a fairly constant level during the last 2 days, but it is impossible to translate his weight loss into terms of calories withdrawn from store because of the lack of information on water metabolism.

George, therefore, is the only subject from whose data conclusions based on the intake-output basis can, with any reasonable degree of certainty, be drawn. It should be noted that this subject was the only one other than John (who had to go to bed during the very active period as a result of mumps), who had been taking regular exercise during the winter and was therefore least affected by the strenuous physical activities of the 4th–8th experimental days. For him the difference between intake and output over the whole period was less than 3 %. The same degree of agreement might have been obtained by Evan had the experiment been continued for a longer period, but at the end of the 13th day the difference amounted to 4%. The net weight difference over the experimental period for all five subjects amounted to less than 1 kg and the estimated energy value of the food eaten exceeded the estimated energy expenditure by 3 %.

The results therefore show a satisfactory degree of agreement between energy intake, as food, and energy expenditure as determined by the Kofranyi-Michaelis analysis of activities. Had the subjects been more accustomed to the types of activity which they carried out between the 4th and 8th days it can be predicted that the day-to-day difference between intake and output would have been lessened. This last condition would be found in a study of subjects on heavy work continuously, as in some industries.

SUMMARY

1. The Kofranyi-Michaelis calorimeter was used to estimate the energy expenditure of five subjects over a period of 13 days, during 5 of which the subjects carried out tasks involving great energy expenditure.

2. The results were compared with the energy value of the food eaten during the same period.

3. A satisfactory agreement between these two estimates over this comparatively short period was found in spite of the fact that three subjects were affected by the severity of the work involved in some of the tasks for which they were not in training.

4. It is suggested that this technique might be used to estimate the energy expenditure of operatives, especially those engaged in heavy industry.

This experiment would have been impossible without the active co-operation of the subjects, Alistair, Evan, George, John and Iain. They cheerfully undertook the labours of walking under adverse conditions and the monotony of note-taking.

Dr H. E. Magee, Ministry of Health, kindly arranged the supply of two calorimeters from Germany.

We are grateful to Dr C. P. Stewart and the staff of the Clinical Laboratory, Edinburgh Royal Infirmary, for analyses of the food. The Edinburgh Royal Infirmary, and the South-Eastern Regional Hospital Board, Scotland, lent us much valuable domestic equipment. Dr B. Woolf and Miss Joyce Thomson advised and helped with the calculations. Finally, we wish to thank the Medical Research Council for a financial grant which covered the cost of the board for the subjects.

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