Energy intake and expenditure of Indian schoolboys

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1. Sixteen Indian schoolboys, aged 12–14 years and resident in Singapore, were tested for the determination of energy cost, pulmonary ventilation (PV) and oxygen consumption at rest and at various daily activities; their height, body-weight, pulse and blood pressure were also measured. An energy balance study was made by estimating from a diary of measured activities the 24 h energy intake and output.

2. PV and O_2 consumption during running showed positive correlations ($r = 0{\cdot}4$ and $r = 0{\cdot}3$ respectively) with mean height and body-weight. High positive correlations ($r = 0{\cdot}8$) were obtained between mean post-exercise recovery pulse, O_2 consumption and PV.

3. The daily mean calorie intake and output of the subjects were found to be 2108 kcal (8·85 MJ) and 1811 kcal (7·60 MJ) respectively.

4. The boys gained an average of 2·2 kg in weight and 0·7 cm in height in 2 months. They did not suffer from any mental retardation, they were physically fit, free from disease and did their daily routine work satisfactorily.

Except for two studies, by Taylor, Lamb, Robertson & MacLeod (1948) and Taylor, Pye, Ellis & Godshall (1951–2), on energy expenditure in European children, there is very little information about the relationship of age, body-weight, height, blood pressure, pulse rate and oxygen intake to the daily calorie intake and expenditure of energy of Asian children. To provide more information on these matters, the study now described was undertaken with Indian boys as subjects.

METHODS

Subjects

Sixteen Indian schoolboys of Dravidian stock, aged 12–14 years, who were residing in a boy's home in Singapore, were selected at random for the test. They were medically examined and were found to be healthy and physically fit.

Procedure

Observations were made on the subjects for 7 consecutive days, during which time they performed various activities in the mornings before they had had any food or drink.

Height, body-weight, pulse and blood pressure. In the morning of the 1st day at the start of the test, before the subjects had had any food or drink, their height (the subjects standing barefoot) and body-weight (each subject clothed in one garment), resting pulse and blood pressure were measured.

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Pulse and blood pressure were also measured at post-exercise recovery (see p. 485).

Measurement of energy expenditure. The energy output of the activities was measured by using a Max Planck respirometer and Lloyds gas analysis apparatus. The details of the method and the precautions that were adopted have been described by Banerjee & Saha (1970). The measurement of energy output of each boy was made on three consecutive mornings for periods ranging between 3 and 10 min for each activity. Rest intervals of 4–10 min were given between tests. After necessary corrections, the average value of O_2 consumption based on measurements that were made for 3 d at each activity of each boy was accepted for calculation of the mean energy expenditure for that activity. The calorie value of O_2 was obtained from the table of Zuntz & Schumberg, modified by Lusk, as given by Oser (1965). The average room temperature and relative humidity at the place of investigation were 29° (range 27–31°) and 75 % (range 70–80 %). The pulmonary ventilation (PV) at each activity was measured by the same respirometer and was corrected to standard temperature and pressure, dry.

Calculation of energy expenditure

The subjects recorded their 24 h energy expenditure by a standard diary method, similar to that used by Garry, Passmore, Warnock & Durnin (1955), to record the time spent on various activities. Under the supervision of the warden of the home each boy supplied, on the work-diary sheet provided, a detailed time-record of his various activities for each 24 h period for the 7 d; the entries were checked each day. The energy costs per min of all activities were measured except for bathing, toilet, dressing and eating: on the basis of measurement in other activities, the average energy cost of these four activities was taken as 1·5 kcal (0·0063 MJ)/min (see Table 2). The energy cost of sleeping was equated with that of lying at rest. The average durations (timed in min) of various activities were noted from observations for 7 d of such durations at each activity of all the boys. The estimate for the total 24 h expenditure for all activities was calculated by summing the products obtained from multiplying the duration (expressed in min) of each activity by the energy expenditure (kcal/min) for that activity.

Calculation of food intake

The total food intake of the boys was measured daily by the individual method of Durnin & Brockway (1959). Each item of food ready for cooking was separately weighed and recorded by the warden for the 7 d of the study and the average quantity of each item that was eaten by each boy per d was calculated. The inevitable minor variations in food intake were ignored. The calorie values, and the carbohydrate, fat and protein contents of these items of food were obtained from the tables given by Oser (1965), from which the total 24 h intake was calculated. The records were submitted daily by the warden for checking.

Activities

The boys performed daily for 7 d the various activities barefoot, which was their usual way of performing their daily tasks. The mean duration of each particular

activity was calculated from observations that were made, throughout the 7 d, of the duration of each activity by each boy.

For activities *e*, *f*, *g*, *h* and *i*, the respirometer was carried on the back of the subject. In activities *h* and *i*, a lift was used for returning the boys to the floor from which they commenced their ascents and descents of the stairs: during these journeys by lift, the respirometer was disconnected (the time taken by the lift to travel between floors was 16 s).

(*a*) *Lying in absolute rest.* Early in the morning, after the boys had rested lying in bed for about 15 min, measurement was made for 10 min.

(*b*) *Sitting at rest.* After 5 min spent in sitting at ease on getting up from the above lying position, measurement was made for 10 min.

(*c*) *Sitting reading.* After activity *b*. The same reading material was given to all the boys and measurement was made for 10 min.

(*d*) *Sitting writing.* After activity *c*. The same writing material was given to all the boys and measurement was made for 10 min.

(*e*) *Standing.* After activity *d*. Measurement was made for 10 min. As a diversion, the subjects were asked to watch the gas analysis.

(*f*) *Walking.* After activity *e*. Each boy walked a measured horizontal distance (100 m) for 10 min. The average speed was 5·1 km/h (range 4·0–6·9 km/h).

(*g*) *Running.* After activity *f*. Each boy ran a measured horizontal distance (100 m) for 5 min. The average speed was 8·5 km/h (range 6·0–9·9 km/h).

(*h*) *Ascending stairs.* After activity *g* and 10 min rest, each boy repeatedly climbed up flights of fifty-eight steps (each 16·5 cm high) for 3 min from the ground floor to the second floor. The average speed was 142 steps/min (range 100–199 steps/min).

(*i*) *Descending stairs.* After activity *h* and 10 min rest, each boy repeatedly descended the same flights of steps for 3 min from the second floor to the ground floor. The average speed was 158 steps/min (range 120–199 steps/min).

(*j*) *Post-exercise recovery.* After activity *i* and 10 min rest, each boy ran the same measured distance (100 m) with the same speed range as in activity *g* for 5 min and then immediately settled down in a chair and was connected to the respirometer with the nose closed. His pulse and blood pressure were also measured till these returned to the pre-exercise levels.

RESULTS

Age, body-weight, height, pulse and blood pressure

Age, body-weight and height of the subjects at the start of the test and 2 months later are recorded in Table 1. The mean gains in body-weight and height were 2·2 kg and 0·7 cm respectively.

Pulse rate and blood pressure at rest and immediately after exercise are also shown in Table 1.

Energy expenditure

The duration of each activity, the energy expenditure for each activity and the percentage variation in expenditure at each activity above the value for sitting writing

Table 1. *Age, body-weight and height of sixteen Indian schoolboys initially and 2 months after the test, and pulse and blood pressure*

(Mean values and standard deviations; the SD was calculated from the variation between sixteen boys, representing each boy by the mean of three readings)

Age (years)	13·0 ± 0·60
Body-weight (kg)	
Initial	31·3 ± 5·60
2 months after the test	33·5 ± 5·52
Height (cm)	
Initial	140·6 ± 7·00
2 months after the test	141·3 ± 7·00
Pulse (beats/min)	
Resting	77·8 ± 8·40
Post-exercise recovery	111·0 ± 12·80
Blood pressure (mmHg)	
Systolic, resting	102·2 ± 6·40, post-exercise recovery 123·0 ± 10·00
Diastolic, resting	60·3 ± 6·80, post-exercise recovery 67·8 ± 6·80

are shown in Table 2. The energy expended by the subjects during sitting at ease was significantly more ($t > 3$) than when they were sitting reading or sitting writing.

The highest percentage increase in energy expenditure above the value for sitting writing was in running (456%), closely followed by ascending stairs (422%). In descending stairs, the energy expenditure was about 37% lower than that at ascending stairs and was about 227% more than at sitting writing.

The energy expenditure was lowest in sitting writing, closely followed by sitting reading and lying at rest.

The boys spent about 20 and 18% of the total energy output in sleeping and walking respectively.

PV and O_2 consumption

PV and O_2 consumption were lowest in sitting writing, closely followed by sitting reading and lying at rest (Table 3). Although the PV was highest during the ascent of stairs, the O_2 consumption was slightly higher when running. When descending stairs, PV and O_2 consumption were each about 36% lower than when the subjects were ascending stairs. For post-exercise recovery, PV and O_2 consumption were about 44 and 55% lower respectively than the values for subjects when running. The ratio O_2 consumption:PV gradually rose from 0·024 at lying at rest to 0·036 while running.

Oxygen intake and PV during running were found to have some positive correlation with height ($r = 0·4$ and $r = 0·3$ respectively) and body-weight ($r = 0·5$ and $r = 0·4$ respectively) but no such correlations were found with age. High correlations ($r = 0·8$) were obtained between post-exercise recovery pulse, and O_2 consumption and PV.

Food intake

The items and quantities of food provided for daily per caput consumption, with their carbohydrate, fat and protein contents, and their calorie values are shown in

Table 2. *Energy expenditure in different activities of sixteen Indian schoolboys*

(Mean values and standard deviations; the SD was calculated from the variation between sixteen boys, representing each boy by the mean of three readings)

Activity	Daily duration (min)	Energy expenditure				Percentage variation from lowest kcal/min value recorded at sitting writing	Energy expenditure		Percentage variation from lowest kcal/kg per h value recorded at sitting writing
		kcal/min*	MJ/min†	Per 24 h kcal	Per 24 h MJ		kcal/kg per h	kJ/kg per h	
Lying at rest (including sleeping)	420	0·86 ± 0·20	0·0036	361·20	1·51	+5	1·64 ± 0·32	6·8	+3
Sitting at ease	150	0·98 ± 0·16	0·0041	147·00	0·61	+20	1·86 ± 0·20	7·8	+17
Sitting reading	330	0·82 ± 0·16	0·0034	270·60	1·13	0	1·59 ± 0·28	6·6	+0·6
Sitting writing	90	0·82 ± 0·20	0·0034	73·80	0·31	—	1·58 ± 0·32	6·6	—
Standing	90	1·03 ± 0·20	0·0043	92·70	0·39	+26	1·81 ± 0·24	7·6	+15
Walking, speed 5·1 km/h	150	2·10 ± 0·44	0·0088	315·00	1·32	+156	3·66 ± 0·56	15·3	+132
Running, speed 8·5 km/h	60	4·56 ± 0·60	0·0191	273·60	1·15	+456	7·94 ± 0·84	33·3	+403
Ascending stairs, speed 142 steps/min	12	4·28 ± 0·80	0·0179	51·36	0·22	+422	7·47 ± 0·88	31·3	+373
Descending stairs, speed 158 steps/min	8	2·68 ± 0·56	0·0112	21·44	0·09	+227	4·72 ± 1·00	19·7	+198
Post-exercise recovery	10	2·38 ± 0·64	0·0099	23·80	0·10	+190	4·22 ± 0·96	17·7	+167
Bath, toilet, dressing and eating	120	1·50 (assumed)	0·0063	180·00	0·75	+83	2·87	12·0	+81
Total	1440			1810·50	7·60				

* Total energy expenditure/24 h was calculated to be 1811 kcal (7·606 MJ) and total energy intake in 24 h was 2108 kcal (8·854 MJ) (see Table 4); thus, 24 h balance was +297 kcal (1·247 MJ).

† 100 kcal = 0·42 MJ.

Table 3. *Pulmonary ventilation (PV) and oxygen consumption in different activities of sixteen Indian schoolboys*

(Mean values and standard deviations; the SD was calculated from the variation between sixteen boys, representing each boy by the mean of three readings)

Activity	PV (l/min)	Percentage variation from lowest PV l/min value recorded at sitting writing	O_2 consumption (l/min)	Percentage variation from lowest O_2 l/min value recorded at sitting writing
Lying at rest	7·34 ± 1·68	+24	0·181 ± 0·04	+3
Sitting at ease	8·00 ± 1·28	+35	0·200 ± 0·04	+14
Sitting reading	5·94 ± 1·48	+0·1	0·175 ± 0·04	0
Sitting writing	5·93 ± 1·48	—	0·175 ± 0·04	—
Standing	7·20 ± 1·48	+21	0·209 ± 0·04	+19
Walking, speed 5·1 km/h	13·06 ± 2·48	+120	0·447 ± 0·08	+155
Running, speed 8·5 km/h	25·56 ± 2·68	+331	0·925 ± 0·12	+428
Ascending stairs, speed 142 steps/min	26·19 ± 2·98	+341	0·845 ± 0·16	+383
Descending stairs, speed 158 steps/min	16·89 ± 3·20	+185	0·544 ± 0·12	+210
Post-exercise recovery	14·24 ± 2·40	+140	0·466 ± 0·12	+166

Table 4. *Daily per caput food items eaten by sixteen Indian schoolboys*

(Mean values from observations for 7 d)

Food item	Quantity, uncooked but dressed (g)	Carbohydrate (g)	Fat (g)	Protein (g)	Energy intake (kcal)
Rice	320	254·00	0·96	24·30	1158·40
Wheat	80	59·20	1·06	9·60	292·20
Bread (one slice)	23	11·80	0·51	1·95	59·50
Noodle	32	4·10	0·20	0·71	21·40
Egg, one	54	0·40	6·20	6·90	87·40
Butter	8	—	6·50	—	57·30
Cooking oil	8	—	8·00	—	70·70
Soya bean	8	3·00	0·50	3·40	21·10
Vegetables, mixed	60	7·20	0·20	2·40	36·60
Fruits, mixed	136	19·00	0·41	0·95	76·10
Milk (half a cup)	144	7·00	5·62	5·04	98·00
Sugar	16	16·00	—	—	62·00
Pulses (lentils, split and dried)	20	12·00	0·24	4·80	67·80
Total		393·70	30·40	60·05	2108·30

Table 4. The average food intake provided 2108 kcal (8·85 MJ), with more than 70 % of the calories being derived from carbohydrates. The subjects consumed daily only 30 g fat and 60 g protein.

Relationship between calorie intake and energy expenditure

The mean daily energy expended by the boys was 1811 kcal (7·60 MJ) (see Table 2, footnote) and their mean daily intake was 2108 kcal (8·85 MJ) (Table 4), thus giving a surplus of 297 kcal (1·24 MJ).

DISCUSSION

According to the recommendation of the Food and Nutrition Board of the National Research Council of the USA (as quoted by Oser, 1965), the weight and height of boys aged 12–15 years should be 45·0 kg and 156·0 cm respectively. Our subjects were smaller, with a mean body-weight of 31·3 kg and a mean height of 140·6 cm: these values were lower than those of European boys aged from 8 years and 9 months to 10 years and 11 months that were reported in the study by Taylor *et al.* (1951–2). In our study, the resting blood pressure was found to be 102/60 mm Hg: this is low compared with the figures quoted by Spector (1961).

Although we found some positive correlation of O_2 intake and PV during running with height and body-weight, we did not find any such correlation with age: Wilmore & Sigerseth (1967), however, with the same activity obtained relatively high correlations with age, height and body-weight. The O_2 intake and PV of our subjects during running were much lower than those reported in the study of Wilmore & Sigerseth (1967). This might be due to the lower body-weight and height of our subjects.

The finding that energy expenditure during sitting at ease was significantly more than that expended by subjects sitting reading and sitting writing is in agreement with our earlier findings (Banerjee & Saha, 1970) and might be due to concentration of mind on reading and writing, which reduced the PV and O_2 consumption.

Taylor *et al.* (1948) showed that boys, aged 12–14 years and of body-weight 41 kg, spent 1·4 kcal (0·0058 MJ) per min while sitting and playing at puzzles. The boys whom we studied were of the same age range but with a lower body-weight; they spent only 0·82 kcal (0·0033 MJ) per min while sitting reading, an activity that may be considered equivalent to sitting and playing at puzzles: even while standing, these boys spent only 1·03 kcal (0·0043 MJ) per min.

Taylor *et al.* (1951–2) found that the average energy expenditure of boys at sitting drawing was $2{\cdot}00 \pm 0{\cdot}24$ kcal (0·0080 MJ) per kg per h. On equating the sitting drawing with the sitting writing of our study, it was seen that the boys whom we studied expended only $1{\cdot}58 + 0{\cdot}32$ kcal (0·0066 MJ) per kg per h, which was significantly lower ($t > 4$) than the value found by Taylor *et al.* (1951–2).

The highest percentage increase in energy expenditure above the value for sitting writing was in running, closely followed by ascending stairs: in our previous study (Banerjee & Saha, 1970), the same trend was also observed.

Consideration of the ratio O_2 consumption: PV shows that with increase in severity of the activity there was an increase of gas transfer, i.e. the rate of O_2 intake per min from the lung was more than the value for lying at rest or sitting at ease, and this rate of increase reflected the functional condition of the O_2 transport system.

Although there was a surplus energy balance, the diet was not at all balanced, most of the calories being derived from carbohydrates, and it fell far short of the recommendations of the FAO (1957) and of the Food and Nutrition Board of the National Research Council of the USA (see Oser, 1965), whether related to age or weight.

In comparison with our findings, Banerjee & Mahindra (1962) found an even lower calorie intake (1406 kcal (5·70 MJ) (and expenditure (1410 kcal (5·92 MJ)) in college

girls in India. In our earlier studies (Banerjee, Lal & Saha, 1965; Banerjee & Saha, 1970), we found similar, low calorie intakes (1905 kcal (8·00 MJ)) in medical students in India, and low calorie intake and expenditure in women police of Singapore. However, despite these inadequacies the daily surplus of calories was reflected in the gain in body-weight and the increase in height in 2 months. Moreover, some of the boys showed the physical changes of puberty which might be additional contributory factors for this relatively large gain in body-weight (2·2 kg in 2 months). Furthermore, they did not suffer from any retardation of mental growth, as was proved by the fact that they read at the same standard (classed as satisfactory) as students of other races, including European children of the same age-group.

As has been stated by the FAO (1957), the influence of undernutrition during one or several generations on the growth rate and calorie requirements of these young children has not yet been fully investigated and assessed.

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