No major differences in energy metabolism between matched and unmatched groups of 'large-eating' and 'small-eating' men

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Rates of energy expenditure (J/kg fat-free mass (FFM) per min) in normal weight, 'small-eating' men were compared with those obtained for normal weight (*n* 8) and underweight (*n* 5) 'large-eating' men. For the matched groups of 'large-' and 'small-eaters' there were no differences in resting metabolic rate (RMR) measurements but during controlled daily activities there was a small but significant increase ($P < 0.05$) in energy expenditure in the 'large-eaters'. These results contrast with those obtained for the unmatched groups where energy requirements were about 10% ($P < 0.01$) higher in the underweight 'large-eaters' at rest but were not different during the more energetic (walking) activities. However, after adjustment for differences in FFM between these two groups, the resting energy expenditures of the 'large-eaters' (82·54 (SE 1·51) J/kg FFM per min) were similar to those of the 'small-eaters' (81·87 (SE 1·51) J/kg FFM per min). Oral temperatures were significantly higher in the matched (0·35–0·65°) and unmatched (0·7–0·9°) 'large-eaters' both at rest and during the different activities, but the thermic effect of food (50 kJ/kg FFM) was one fifth lower (not significant) in both groups of 'large-eaters'. These results provide little evidence for any major metabolic differences between groups of 'large-eating' and 'small-eating' men.

Energy metabolism: Indirect calorimetry: Food intake: Men

There have been three detailed comparative investigations on rates of energy expenditure at rest and during different daily activities in normal weight subjects who consider that they are either 'large-eaters' or 'small-eaters'. In the first of these studies Rose & Williams (1961) were unable to demonstrate any significant differences in laboratory-measured rates of O_2 consumption between their two groups of male volunteers (*n* 12) who were matched for age, height and weight. Nearly 30 years later McNeill *et al.* (1989) reported very similar rates of energy expenditure at rest, while sleeping and during controlled walking or cycling activities for ten, young male 'large-' or 'small-eaters' who were matched for age, weight, height and body fat (BF) content. Unlike these two studies our recently published data demonstrated that rates of energy expenditure at rest and during different light daily activities could vary by as much as 35% between groups of normal weight 'large-eating' (*n* 9) and 'small-eating' (*n* 9) female subjects (Clark *et al.* 1992). There appear to be two

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possible explanations for the quite disparate sets of results which were obtained in these three studies. The first relates to the sex of the volunteers (see also Garrow, 1985) and the second to the fact that most of the 'large-eating' females were not, strictly speaking, within the normal weight range; their body mass index (BMI; weight (kg)/height $(m)^2$) values (18·96 SE 0·52) demonstrate that most of the 'large-eating' subjects were underweight (Clark *et al.* 1992).

In the present investigation we have compared rates of energy expenditure in normal weight 'small-eating' males with those obtained for groups of normal and underweight 'large-eating' males to determine whether gender or thinness is responsible for the differences in energy expenditure observed with 'large-' and 'small-eating' females (Clark *et al.* 1992).

METHODS

Subjects

Healthy, normal weight, non-smoking 20- to 50-year-olds who perceived themselves as being 'large-eaters' or 'small-eaters' were recruited by newspaper advertisement. All volunteers (*n* 312) were mailed a comprehensive, food-frequency questionnaire (Baghurst & Baghurst, 1981) that also contained questions on health, medication, physical characteristics and daily activity patterns. When returned the questionnaires were coded to determine apparent daily energy intake and subject suitability. Questionnaire respondents who met the set limits of age, weight and health (*n* 260) were delivered self-reporting food and activity diaries (Ludbrook & Clark, 1992) which were maintained over the same 5 d, Friday-to-Tuesday-inclusive, period (Clark *et al.* 1992). Apparent daily energy intake (I) was determined using an in-house, purpose-written, computer program which used nutrient data based on *McCance and Widdowson's The Composition of Foods* (Paul & Southgate, 1978); apparent daily energy expenditure (E) was calculated from energy expenditure data compiled by McArdle *et al.* (1986) and the subject's weight on that day. Dietary protein intake estimated from the excretion of urinary N for 24 h starting at about 07·00 hours on the last day of diary maintenance (Tuesday) was compared to that obtained from the dietary analysis of the food diary for the final 1 d (Study 1) or 2 d (Study 2) of diary recording; this latter result was halved before comparison with the urinary N result (Isaksson, 1980; Warwick *et al.* 1988).

Subjects at opposite extremes of the distribution for E:I were selected to form the study groups of 'large-eaters' (E:I $<$ 1) and 'small-eaters' (E:I $>$ 1).

Protocol

Selected 'large-eating' and 'small-eating' subjects attended the Exercise Physiology Laboratory (EPL) at 7 d intervals on three (Study 2) or four (Study 1) separate occasions. They were 12 h post-absorptive, had refrained from overt physical activity for at least 24 h, and were driven to the EPL so that they arrived in a rested state at about 08·20 hours. After about 50 min supine relaxation energy expenditure at rest (09·20–09·30 hours and 09.40–09.50 hours), while sitting (10.05–10.15 hours), standing (10.30–10.40 hours) and walking on a treadmill at 2·4 (10.55–11.00 hours and 11.00–11.05 hours), 3·9 (11.15–11.20 hours and 11.20–11.25 hours), and 5·4 (11.35–11.38 hours and 11.38–11.41 hours) km/h was measured by indirect calorimetry (Clark *et al.* 1992). Each subject's resting energy requirements were assessed at the same time on every visit to the EPL. Percentage BF was determined by underwater weighing at the conclusion of the walking measurements and the result obtained was used to calculate the subject's fat mass (FM) and fat-free mass (FFM). In Study 2 all the above measurements were performed during the first day's visit to the

EPL but in Study 1 the first visit was used mainly for subject acclimatization with measurements of energy expenditure at rest (09.20–09.30 hours and 09.40–09.50 hours), sitting and standing only: this was followed by treadmill walking practice. For the volunteers in Study 1 all the measurements detailed above, including the underwater weighing, were completed on the second visit to the EPL.

Thermic effect of food (TEF) measurements were continued for 265 min after the consumption of a standard liquid meal (Ensure Plus; Abbott Australasia Pty. Ltd., Sydney, Australia; consisting of (g/kg) carbohydrate 533, fat 320, protein 147, 50 kJ/kg FFM) which was consumed within 15 min on either the ultimate or penultimate visit to the laboratory. The same protocol was followed on the control day (the ultimate visit for half of the subjects) except that each subject remained fasted until the completion of the day's measurements (about 15.30 hours).

Indirect calorimetry

All indirect calorimetric measurements were performed in the EPL using standardized conditions and normal practices (Clark *et al.* 1992). Subjects breathed through a Hans Rudolph (Model 2600) respiratory valve and the expirate was collected in a 150 litre Douglas bag. The O_2 and CO_2 contents of dry expired gas were determined with an Electrochemistry S-3A and a Beckman LB-2 analyser, respectively. These were calibrated before each reading using Lloyd-Haldane verified dry gas mixtures. Expired gas volumes were measured using a calibrated Singer DTM-325 gas meter with a digital read-out. $\dot{V}_{O_2}$, $\dot{V}_{CO_2}$ (ml/kg per min) and respiratory quotient (RQ) values were determined using the classical transformation (Geppert & Zuntz, 1888).

Densitometric analysis

Body density was determined by underwater weighing (Goldman & Buskirk, 1961) and residual lung volume by the helium dilution method (Meneely & Kaltreider, 1949). The Siri (1961) equation was used to convert body density to percentage BF.

Protein turnover

Whole-body protein turnover was determined using ^{15}N-glycine essentially as described by Fern *et al.* (1981) and the rate of breakdown of muscle protein was assessed from the urinary excretion of N^{τ}-methylhistidine and creatinine over a 48 h period 3 d after commencing a meat-free diet (Thompson & Tomas, 1987).

Urinary nitrogen

Urine samples were assayed for N using a N analyser (NA 1500, Carlo Erba Instrumentazione, Milan, Italy). Protein intake was estimated as (urinary N(g) + 2) × 6·25 (Isaksson, 1980).

Statistical analyses

Descriptive data including body composition, plasma variables and diary information for the groups were compared using the independent Student's *t* test. The indirect calorimetric measurements were assessed by analyses of variance. The series of measurements made during the assessment of resting metabolic rate (RMR) on each visit to the EPL and of metabolic rate (MR) during the control period for the TEF were each analysed by a repeated measures design ANOVA. After establishing that the individual regressions for each group included in the analyses were not significantly different, RMR was also analysed by analyses of covariance with FFM as the covariate. The relationships between diary and urinary N estimates of protein intake were examined by regression analyses.

RESULTS

Study 1. Matched, normal-weight 'large-eating' and 'small-eating' subjects

As a substantial number of the subjects who volunteered to take part in this investigation could be classified as 'large-eaters' (where I > E was significant), it was possible to select eight from this group to match nearly the eight apparent 'small-eaters' (E:I $\geqslant$ 1·4) who were willing to complete the calorimetric studies. The physical characteristics of the selected, matched, near normal weight 'large-eating' and 'small-eating' study groups together with their values for I, E and E:I are shown in Table 1. There were no significant differences in weight and BMI between the two groups but the 'large-eaters' were 7 cm ($P < 0·05$) taller than the 'small-eaters'. Although the densitometric measurements of the sixteen subjects demonstrated that percentage BF was one third ($P < 0·05$) greater in the 'small-eaters', there were no statistically significant differences in FM or FFM between the two groups (Table 1).

In the 'large-eaters', I, as assessed using 5 d self-reporting, weighed food diaries, was nearly double ($P < 0·001$) that of the 'small-eaters' (Table 1). Conversely, E, assessed using 5 d activity diaries, was one fifth ($P < 0·05$) less in the 'large-eaters' (Table 1). During these diary measurements protein intake, estimated from urinary N excretion (Isaksson, 1980; Warwick *et al.* 1988) was 78 (SE 13) and 120 (SE 18)% (*n* 6 in each group, not significantly different) of that estimated from the food diaries of the 'large-eaters' and 'small-eaters' respectively (see p. 394).

Resting $\dot{V}_{O_2}$ was similar for both experimental groups (Table 2). This was also the case during the control period for the TEF measurements (Table 2) and during more energetic activities (sitting, standing and walking at 2·4, 3·9 and 5·4 km/h; Table 2). The average RQ tended to be greater in the 'large-eaters' but only attained statistical significance ($P < 0·001$) when energy expenditure was increased (Table 2; Figure 1*a*). An increase in RQ, indicative of a greater utilization of carbohydrate relative to that of fat, was also observed with both the 'large-' and 'small-eaters' with increasing physical activity ($P <$ 0·001). Rates of energy expenditure (J/kg FFM per min) were comparable for both experimental groups at rest (Table 2) but during the different physical activities there was a small yet significant increase ($P < 0·05$) in these rates in the 'large-eaters' (Table 2).

Oral temperature at rest was consistently about 0·35° ($P < 0·05$) higher in the 'large-eaters' and this difference increased to about 0·65° ($P < 0·001$) during the different activities (Table 2).

There were no significant differences between the groups for either the rates of whole-body protein turnover or muscle protein breakdown (Table 3).

Study 2. Unmatched 'large-eating' and 'small-eating' subjects

Although it would have been possible to match the five near normal weight 'small-eaters' (E:I $\geqslant$ 1·5) with five 'large-eaters' of similar age, weight and height, it was decided to select the five 'large-eaters' with the lowest BMI values (see p. 394). Consequently this part of the investigation (Study 2) was performed with unmatched groups of 'large-eaters' and 'small-eaters'. The physical characteristics of the selected volunteers together with their I, E and E:I values are shown in Table 4. The selected 'small-eaters' were more than 20 kg ($P < 0·001$) heavier than the 'large-eaters' and, as a partial consequence of this, their BMI values were also one quarter ($P < 0·001$) greater (Table 4). The densitometry measurements demonstrated that FFM was more than one fifth ($P < 0·001$) higher and FM more than twice ($P < 0·05$) as great in the 'small-eaters'.

I, as determined by diary analysis, was 37·5% ($P < 0·001$) greater in the 'large-eaters'

Table 1. *Physical characteristics and energy balance† in eight, weight-matched, non-smoking 'large-eating' and 'small-eating' male subjects‡*

								Energy (MJ/d)			
								Intake (I)		Expenditure (E)	
Subject	Age (years)	Height (m)	Wt (kg)	BMI	Fat-free mass (kg)	Fat mass (kg)	Body fat (%)	Q	Diary	Diary	E:I§
'Large-eaters'											
PL 176	45	1·83	73·27	21·9	61·91	11·36	15·5	18·58	16·71	13·41	0·80
ST 107	27	1·85	93·60	27·4	75·25	18·35	19·6	15·54	18·85	14·62	0·78
DD 200	29	1·88	70·31	19·9	61·87	8·44	12·0	17·06	20·42	11·05	0·54
PD 037	25	1·88	89·00	25·2	75·03	13·97	15·7	34·02	21·63	16·92	0·78
RM 063	26	1·84	74·15	21·9	64·62	8·20	11·3	15·99	19·23	14·08	0·73
JD 294	34	1·75	69·26	22·6	54·66	14·60	21·1	9·82	14·31	10·06	0·70
JR 285	40	1·84	73·52	21·7	65·43	8·09	11·0	13·40	23·65	14·88	0·63
AT 265	35	1·87	69·60	19·9	58·24	11·36	16·3	9·27	15·09	10·79	0·72
Mean	32·6	1·84*	76·59	22·6	64·63	11·80	15·3*	16·71*	18·74***	13·23*	0·71***
SE	2·5	0·01	3·31	0·9	2·59	1·29	1·3	2·74	1·14	0·84	0·03
'Small-eaters'											
MW 143	43	1·83	79·68	23·8	58·40	21·27	26·7	6·88	8·03	14·52	1·81
CL 190	31	1·78	88·16	27·8	70·26	17·89	20·3	8·52	10·06	16·82	1·67
GG 196	39	1·88	74·78	21·2	61·99	12·79	17·1	9·64	9·27	14·75	1·59
CC 031	38	1·80	79·71	24·6	64·64	15·07	18·9	11·48	9·48	14·44	1·52
DV 011	25	1·65	61·43	22·6	54·73	6·70	10·9	7·82	8·73	12·17	1·39
JP 162	30	1·70	79·79	27·6	58·09	21·70	27·2	6·42	10·34	20·64	2·00
TM 023	42	1·77	80·10	25·6	62·90	17·20	21·5	10·80	11·98	22·48	1·88
RO 153	49	1·73	74·78	25·0	58·88	15·90	21·2	5·86	10·04	16·06	1·60
Mean	37·1	1·77	77·30	24·8	61·24	16·07	20·5	8·43	9·74	16·48	1·68
SE	2·8	0·03	2·70	0·8	1·70	1·71	1·8	0·73	0·42	1·22	0·07

BMI, body mass index (weight (kg)/height (m)^2); Q, questionnaire.
Mean values were significantly different from those for 'small-eaters' (Student's *t* test): * $P < 0·05$, *** $P < 0·001$.
† For details of procedures, see pp. 394–395
‡ For details of subjects, see p. 394.
§ Diary results.

Table 2. *Indirect calorimetric measurements† in groups of eight, weight-matched, non-smoking 'large-eating' (LE) and 'small-eating' (SE) male subjects‡*

(Mean values with their standard errors)

		RMR												Walking					
		Day 2		Day 3		Day 4		Control§		Sitting		Standing		2·4 km/h		3·9 km/h		5·4 km/h	
Variable	Group	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
O_2 consumption	LE	3·96	0·11	3·98	0·10	3·87	0·06	4·03	0·08	4·32	0·10	4·63	0·10	10·18	0·24	12·06	0·24	15·93	0·31
(ml/kg FFM per min)	SE	4·01	0·13	4·02	0·13	4·07	0·10	4·06	0·12	4·23	0·10	4·35	0·12	9·86	0·20	11·74	0·21	16·02	0·36
Respiratory quotient	LE	0·81	0·02	0·87	0·05	0·78	0·01	0·81	0·03	0·79	0·03	0·81	0·03	0·81	0·02	0·82	0·01	0·84**	0·02
	SE	0·78	0·01	0·80	0·02	0·78	0·01	0·77	0·01	0·77	0·01	0·77	0·01	0·78	0·02	0·79	0·01	0·79	0·01
Energy expenditure	LE	79·9	2·5	81·6	2·9	77·4	1·3	81·3	2·3	87·4	2·5	93·3	2·5	206	4·6	243	4·2	323	5·9
(J/kg FFM per min)	SE	80·3	2·5	80·7	2·5	80·7	2·1	81·0	2·4	84·1	2·1	86·6	2·5	197	3·8	235	4·6	323	7·5
Oral temperature (°)	LE	36·3*	0·1	36·0	0·1	36·0	0·1	36·0	0·1	36·1	0·1	36·2*	0·1	35·7	0·2	35·5	0·3	35·7	0·3
	SE	35·7	0·2	35·7	0·1	35·8	0·1	35·7	0·2	35·8	0·2	35·5	0·2	35·0	0·3	35·1	0·3	34·7	0·4

RMR, resting metabolic rate; FFM, fat-free mass.

Mean values were significantly different from those for 'small-eaters' (Student's t test): * $P < 0·05$, ** $P < 0·01$.

† For details of procedures, see p. 395.

‡ For details of subjects, see Table 1 and p. 394.

§ Mean value during control period for thermic effect of food measurements.

Table 3. *Rates of whole-body protein turnover and muscle protein breakdown† in groups of eight, weight-matched, non-smoking 'large-eating' and 'small-eating' male subjects‡*

(Mean values with their standard errors)

	'Large-eaters'		'Small-eaters'	
	Mean	SE	Mean	SE
Whole-body protein turnover (g/kg FFM per 9 h)	1·43	0·06	1·51	0·13
Muscle protein breakdown (% per d)	0·85	0·02	0·90	0·05

FFM, Fat-free mass.

† For details of procedures, see p. 395.

‡ For details of subjects, see Table 1 and p. 394.

and E was nearly one third ($P < 0{\cdot}01$) lower than that of the 'small-eaters' (Table 4). Protein intakes, estimated from 24 h urinary N excretion, were 74·5 (SE 7) (n 4) and 110 (SE 6)% (n 5; $P < 0{\cdot}01$) of those determined from analyses of the self-reporting weighed food diaries (see p. 394) for the 'large-eaters' and 'small-eaters', respectively. These results, when coupled with those obtained with the matched 'large-eaters' and 'small-eaters' (see p. 396), suggest that a consistent bias may be present in the diary estimates of energy intake for the selected groups but it accounts for only a part of the difference in intakes, even when corrected for body weight.

Rates of O_2 consumption at rest on the second and third visits to the EPL and during the control period for the TEF measurements were nearly one twelfth ($P < 0{\cdot}05$) higher in the unmatched 'large-eaters' (Table 5). Resting energy requirements (J/kg FFM per min) during the same series of measurements were one tenth ($P < 0{\cdot}01$) greater in these 'large-eaters' but this difference was reduced to zero as rates of energy expenditure were raised by increased physical activity (Table 5). In all but one of these series of measurements (RMR, day 3) the RQ were higher in the 'large-eaters' but, as was the case with the matched groups (Table 2), this difference only attained statistical significance ($P < 0{\cdot}01$) when energy expenditure was increased by the different physical activities (Table 5).

In the resting state the oral temperature of the 'large-eaters' was 0·7° ($P < 0{\cdot}001$) higher than that of the 'small-eaters'; during the different activities the difference was nearly 0·9° ($P < 0{\cdot}001$; Table 5).

TEF in matched and unmatched 'large-' and 'small-eating' subjects

Neither $\dot{V}_{O_2}$, $\dot{V}_{CO_2}$ nor the calculated rates of energy expenditure had returned to basal values within 4 h of consuming the standardized liquid meal in either the study with the matched (Fig. 1a) or the unmatched (Fig. 1b) groups of 'large-eaters' and 'small-eaters'. The average TEF in the 'small-eaters' (6·65 (SE 0·93) and 6·74 (SE 0·39)% of the energy in the test meal for the matched and unmatched groups respectively) was not significantly different from that for the respective 'large-eating' groups (5·55 (SE 1·12) and 5·20 (SE 1·33)%).

Table 4. *Physical characteristics and energy balance† in unmatched, non-smoking 'large-eating' and 'small-eating' male subjects‡*

Subject	Age (years)	Height (m)	Wt (kg)	BMI	Fat-free mass (kg)	Fat mass (kg)	Body fat (%)	Energy (MJ/d): Intake (I): Q	Energy (MJ/d): Intake (I): Diary	Energy (MJ/d): Expenditure (E): Diary	E:I
'Large-eaters'											
MM 408	29	1·73	56·95	19·03	51·48	5·47	9·6	10·55	14·20	12·26	0·86
SM 502	44	1·69	65·45	22·92	54·52	10·93	16·7	17·61	16·69	12·26	0·73
CM 533	46	1·77	67·25	21·47	57·50	9·75	14·5	7·22	14·53	11·37	0·78
IS 571	21	1·77	56·20	17·92	51·99	4·22	7·5	15·03	13·29	9·17	0·69
DH 606	23	1·88	63·33	17·92	53·39	9·94	15·7	16·83	15·60	12·18	0·78
Mean	32·6	1·77	61·84***	19·86***	53·78***	8·06*	12·8	13·45	14·86***	11·45**	0·77***
SE	5·2	0·03	2·24	1·00	1·07	1·34	1·8	1·98	0·59	0·59	0·03
'Small-eaters'											
RC 460	46	1·88	86·30	24·42	62·91	23·39	27·1	9·25	8·52	12·74	1·50
PH 478	40	1·70	74·65	25·83	65·17	9·48	12·7	9·90	11·72	17·61	1·50
DS 486	44	1·87	91·15	26·07	65·17	25·98	28·5	11·08	11·19	17·98	1·61
RT 535	39	1·87	80·48	23·01	61·65	18·83	23·4	6·99	9·46	14·28	1·51
GQ 597	31	1·81	80·33	24·52	72·30	8·03	10·0	12·31	13·17	20·58	1·56
Mean	40·0	1·83	82·58	24·77	65·44	17·14	20·3	9·91	10·81	16·64	1·54
SE	2·6	0·03	2·83	0·55	1·84	3·62	3·8	0·90	0·82	1·40	0·02

BMI, body mass index (weight (kg)/height (m)^2); Q, questionnaire.
Mean values were significantly different from those for 'small-eaters' (Student's *t* test): * $P < 0·05$, ** $P < 0·01$, *** $P < 0·001$.
† For details of procedures, see pp. 394–395.
‡ For details of subjects, see p. 394.
§ Diary results.

Table 5. *Indirect calorimetric measurements† in unmatched, non-smoking 'large-eating' (LE) and 'small-eating' (SE) male subjects‡*

(Mean values with their standard errors)

		RMR												Walking					
		Day 1		Day 2		Day 3		Control§		Sitting		Standing		2·4 km/h		3·9 km/h		5·4 km/h	
Variable	Group	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
O_2 consumption	LE	4·17	0·14	4·21**	0·08	4·11	0·07	4·11*	0·05	4·27	0·15	4·56	0·13	10·52	0·43	12·14	0·41	15·84	0·34
(ml/kg FFM per min)	SE	4·05	0·15	3·78	0·09	3·86	0·15	3·79	0·10	4·08	0·10	4·48	0·17	10·48	0·47	12·48	0·49	16·49	0·64
Respiratory quotient	LE	0·89	0·06	0·84	0·06	0·80	0·03	0·83	0·03	0·81	0·02	0·85	0·05	0·86*	0·01	0·83	0·01	0·85	0·04
	SE	0·84	0·04	0·82	0·02	0·81	0·02	0·78	0·02	0·77	0·03	0·78	0·01	0·80	0·02	0·80	0·02	0·81	0·02
Energy expenditure	LE	85·8	4·0	85·2**	1·7	82·4	1·2	83·7***	1·0	86·0	3·1	92·7	3·1	214	8·7	246	8·6	322	6·5
(J/kg FFM per min)	SE	82·0	2·9	76·3	1·8	77·6	3·1	75·6	1·7	81·4	2·0	89·3	3·1	211	10·0	250	10·0	332	13·8
Oral Temperature (°)	LE	36·3*	0·1	36·3***	0·2	36·0	0·1	36·3***	0·1	36·4***	0·1	36·4***	0·1	35·8	0·3	35·9	0·1	35·7	0·2
	SE	35·8	0·2	35·4	0·2	35·5	0·2	35·4	0·2	35·5	0·2	35·5	0·2	34·8	0·4	35·1	0·4	34·9	0·4

RMR, resting metabolic rate; FFM, fat-free mass.

Mean values were significantly different from those for 'small-eaters' (Student's t test): * $P < 0·05$, ** $P < 0·01$, *** $P < 0·001$.

† For details of procedures, see p. 000.

‡ For details of subjects see Table 4 and p. 000.

§ Mean value during control period for thermic effect of food measurements.

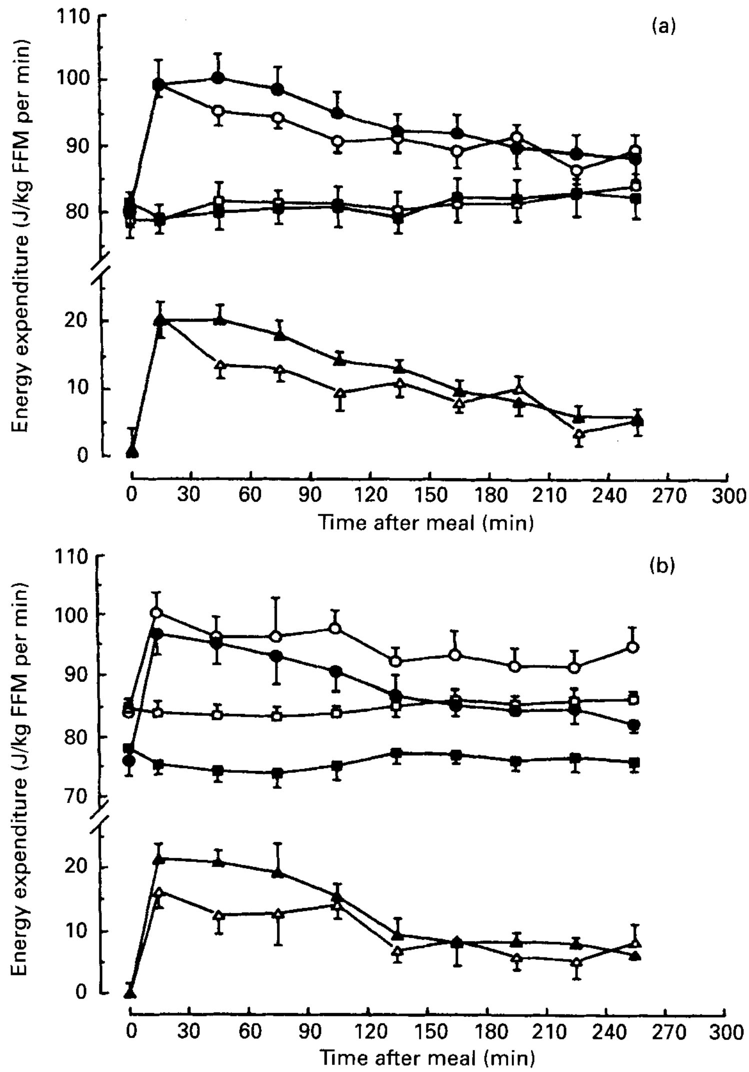

Fig. 1. Rates of energy expenditure while fasting (□; ■), after the consumption of a standardized liquid meal (○; ●) and the net thermic response (△; ▲) in 'small-eating' (■; ●; ▲) and 'large-eating' (□; ○; △) male subjects. Results are presented as group means with standard errors represented as vertical bars for the matched (*n* 16; Fig. 1a) and unmatched (*n* 10; Fig. 1b) studies.

DISCUSSION

Assessment of energy intake and expenditure

Diary techniques were used to estimate energy intake and energy expenditure in the volunteers who regarded themselves as being 'large-eaters' or 'small-eaters'. In the first study the food diary data indicated that I for the 'large-eaters' was nearly twice that for the matched 'small-eaters' (Table 1). These results are very similar to those obtained by Rose & Williams (1961) and McNeill *et al.* (1989) in their studies on energy metabolism in matched 'large-eating' and 'small-eating' young men.

In our study with unmatched groups of male volunteers (Study 2), I for the 'large-eaters' was only 37% greater than that for the appropriate 'small-eating' group (Table 4). This difference between the two studies can be explained by differences in body weight. The 'large-eaters' in the study with matched groups of volunteers (Study 1) were nearly 15 kg ($P < 0.01$) heavier than the 'large-eaters' in the study with unmatched groups of volunteers. When I is expressed per kg body weight, the weight-normalized intakes of the 'large-eaters' (245 and 240 kJ/kg body weight) were nearly twice those of the 'small-eaters' (126 and 131 kJ/kg body weight for Study 1 and Study 2 respectively; Tables 1 and 4).

For the metabolic measurements which formed the principal focus of these studies the selection criteria for metabolically 'efficient' and metabolically 'inefficient' subjects were based on the E:I values obtained from the food and activity diaries. The data in Tables 1 and 4 show that there are large discrepancies in the balance of intake to expenditure within the diary period but these were consistent within each selected group. Obviously there were systematic problems associated either with the recording or with the coding and analysis of the recorded information as the discrepancies in energy balance are not sustainable, especially for the 'small-eaters' (Clark *et al.* 1992). The urinary N excretion indicates some bias in the measurements of protein intake but does not distinguish between under-reporting by the subject or a correctly recorded period of undereating ('dieting') which results in negative N balance.

Despite the problems associated with self-reported diaries from diet-conscious groups (Southgate, 1986; Lissner *et al.* 1989; McNeill *et al.* 1989; Clark *et al.* 1992), the data obtained were used only as part of the selection criteria for the recruitment of two groups, classified as 'large-eaters' and 'small-eaters', which would form the basis for the comparative metabolic measurements. The two groups thus obtained had reported energy intakes similar to those of equivalent groups used by others (Rose & Williams, 1961; McNeill *et al.* 1989). If metabolic efficiency was a contributing factor to the large differences in apparent food intakes then these two groups could be expected to exhibit substantial differences in metabolic rate.

Indirect calorimetry

The data obtained with the matched 'large-' and 'small-eating' male subjects (Study 1; Table 2) show that there are no differences in the rate of energy expenditure (J/kg FFM per min) at rest, in the post-absorptive state, between these two groups of volunteers. However, a higher rate of energy expenditure (about 4%; $P < 0.05$) was observed with the 'large-eaters' when they were involved in normal, light-to-moderate physical activities (Table 2). This small but consistent difference has not been observed in the previous studies with matched male subjects (Rose & Williams, 1961; McNeill *et al.* 1989). RQ values also increased significantly ($P < 0.001$) in this group during the different activities (Table 2). Although these values tended to increase in both the experimental groups with increasing energy expenditure (Table 2), it is unlikely that the observed changes were due to buffering effects on the bicarbonate pool as the exercise levels were well within aerobic capacity (Wasserman & Whipp, 1975). In any case, these non-specific exercise effects would be similar for both experimental groups. The differences in RQ values (Table 2) demonstrate that the 'small-eaters' were more reliant on fat than on carbohydrate for their energy needs than were the 'large-eaters' (Bessard *et al.* 1983).

Despite the increased energy expenditure in the male 'large-eaters' during normal daily activities (sitting, standing, strolling and walking), this difference would account for a maximum of only 0.25 of the about 5.5 extra MJ consumed per d (Table 1).

With the unmatched experimental groups the average rate of energy expenditure (J/kg FFM per min) was around one tenth ($P < 0.01$) higher in the 'large-eaters' at rest (Table 5) but as metabolic rate was increased by light-to-moderate physical activity (walking) this difference was eliminated (Table 5). These latter results are similar to those obtained with near normal weight unmatched groups of 'large-eating' and 'small-eating' female subjects (Study 2, unpublished observations; Clark *et al.* 1992). Thus, unmatched, but not matched, groups of 'large-eaters' have rates of energy expenditure at rest which are significantly higher than those of their selected 'small-eating' counterparts (Tables 2 and 5; McNeill *et al.* 1989; Clark *et al.* 1992; see below). The changes in post-absorptive RQ with increased energy expenditure in the unmatched experimental groups (Table 5) were similar to those found with the matched subjects (Table 2). The lower values obtained for the 'small-eating' males both at rest and during the different activities (Table 5) indicate, once again, a greater reliance on lipid rather than carbohydrate oxidation to meet these subjects' energy requirements (Bessard *et al.* 1983).

Covariate analysis of resting energy expenditure

One feature common to this and to our earlier study (Clark *et al.* 1992), but not to other investigations on energy metabolism in 'large-eating' and 'small-eating' humans, was the high proportion of underweight 'large-eaters'. The BMI values for 60% of the male 'large-eaters' (range 17·9–22·9; Table 4) and nearly 80% of the unmatched female 'large-eaters' (range 16·8–21·5; Table 1; Clark *et al.* 1992) were less than 20. Despite the marked differences in BMI between the female 'large-' and 'small-eaters' (18·96 (SE 0·52) *v.* 23·12 (SE 0·96); $P < 0.001$) FFM were very similar for both experimental groups (40·00 (SE 1·73) *v.* 42·18 (SE 1·46) kg respectively; Clark *et al.* 1992). There were similar differences in BMI between the unmatched 'large-'and 'small-eating' men (Table 4) but with these subjects FFM was nearly one fifth (11·66 kg; $P < 0.001$) lower in the 'large-eaters' (Table 4). Because of this large dissimilarity in metabolically active tissue between the unmatched 'large-' and 'small-eating' men we have employed a more valid approach to the assessment of resting energy expenditure in these subjects. This was accomplished by analysis of covariance using FFM as the covariate (Segal *et al.* 1989). The adjusted means show that there are, in fact, no differences in energy expenditure at rest between the unmatched 'large-eating' (4·92 (SE 0·09) kJ/min) and 'small-eating' (4·88 (SE 0·09) kJ/min) men but the difference between the female 'large-' (3·84 (SE 0·12) kJ/min) and 'small-eaters' (3·46 (SE 0·12) kJ/min; $P < 0.05$) for resting energy expenditure (Clark *et al.* 1992) was retained. Although 'thinness' does not contribute to the differences in resting energy expenditure between groups of 'large-' and 'small-eating' females it appears to be an important factor in the males where the range in FFM was much greater (Table 4).

Energy dissipating processes

Differences in relative efficiency of energy use may arise from differing activities of energy-dissipating or energy-requiring processes. We have measured two of these; TEF and the rate of protein turnover.

Although there were no significant differences in post-prandial thermogenesis between the matched and unmatched 'large-eating' and 'small-eating' males, in both cases the average TEF was 20–30% greater in the 'small-eaters' (Fig 1a, 1b). These data extend and confirm our earlier data with 'large-' and 'small-eating' females (Clark *et al.* 1992) but are at variance with a number of investigations which have reported an increased post-prandial energy expenditure in subjects who were eating to excess (Miller *et al.* 1967; Apfelbaum *et al.* 1971; Morgan *et al.* 1982), or have shown a reduced or blunted response in post-obese subjects (Dore *et al.* 1982; Shah *et al.* 1988; Dulloo *et al.* 1989) and in volunteers on a reduced energy intake (Apfelbaum *et al.* 1969; Bessard *et al.* 1983). Nonetheless, it is obvious that the apparent differences in energy balance between the groups cannot be ascribed to difference in TEF.

The lack of any difference in the rate of protein turnover (Table 3), a process which may account for up to one quarter of energy expenditure at rest (Newsholme, 1980; Waterlow 1986), is consistent with and corroborates the absence of any difference in the calorimetric measurements of RMR between the 'large-' and 'small-eating' males (Table 2).

Oral temperature

The oral temperatures of the volunteers at rest, which we assume reflect core temperatures (Åstrand & Rodahl, 1986), were consistently higher in the 'large-eaters' (Table 2 and 5). This finding could reflect differences in (a) the intensity of oxidative metabolism, (b) the thermal 'set-point' (independent of metabolism) and/or (c) the ability to conserve body heat in the 'small-eaters' and 'large-eaters' (especially those who were thin). As a difference (0·35°) was present between the matched 'large-eaters' and 'small-eaters' in the resting state when $\dot{V}_{O_2}$ was nearly identical for the two experimental groups (Table 2) and there was a difference (0·7°) between the unmatched volunteers during the walking activities when, similarly $\dot{V}_{O_2}$ was virtually the same for both the 'large-' and 'small-eating' men (Table 5), the intensity of oxidative metabolism does not appear to be responsible for the temperature difference. Thus, no firm conclusions can be drawn regarding the significance of the observed differences in oral temperature.

Conclusions

The present study confirms that there are only minor differences in rates of energy expenditure at rest and during different activities between groups of 'large-eating' and 'small-eating' men. For this reason the large differences in apparent daily energy balance (+5·51 to −6·75 MJ/d; Tables 1 and 4) between the two experimental groups must be explained mainly on the basis of errors in the assessment of energy intake and/or energy expenditure using short duration, self-reporting diaries. This view is supported by the average bias in estimated N intake revealed by the measurement of urinary N excretion.

While the results from indirect calorimetry contrast with those obtained with female 'large-' and 'small-eaters' (Clark *et al.* 1992), there remain other similarities between the sexes. Thus, postprandial thermogenesis (after a standardized liquid meal) was always lower in the 'large-eaters' and oral temperatures were always higher in this group.

If there is a major thermogenic difference between 'large-' and 'small-eating' males it is not apparent in fasted subjects in the finely controlled environment of a calorimetry laboratory. Comparative measurements conducted in the free-living state (or the use of different selection criteria) may yield different results, but in the present study there is little support for differences in the relative efficiency of energy metabolism between 'large-eating' and 'small-eating' men.

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