Thermic effect of a meal
1. Methodology and variation in normal young adults

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The variation in the thermic effect of a meal (TEM) was investigated in two groups of five subjects following a standard test meal. Results demonstrated a 50% lower response over 6 h, in the same subjects, when measured intermittently (protocol 2) as compared with a continuous measurement (protocol 1). The variation in TEM among occasions (measured on three occasions in each subject) was large (coefficient of variation (CV) 18·7%, $P < 0·02$). However, the post-meal total energy output (CV 1·4%, $P > 0·05$), non-protein respiratory quotient (CV 1·9%, $P > 0·05$) and substrate oxidation rate were not different ($P > 0·05$) in the same individual on separate occasions. Small variations in the basal metabolic rate (BMR) from occasion to occasion (CV 2·6%) contributed to the variation in TEM. However, after allowing for the changes in BMR, variation in TEM (CV 8·6%, $P > 0·05$) was still sizeable though not statistically significant.

Thermic effect: Methodology: Variation of thermic effect

The suggestion that the thermic effect of a meal (TEM) may be implicated in the pathogenesis of obesity has led to a large volume of work during the last 20 years (Kaplan & Leveille, 1976; Pittet *et al.* 1976; Shetty *et al.* 1981; Golay *et al.* 1982; Zed & James 1982; Bessard *et al.* 1983; Segal *et al.* 1985; Den Besten *et al.* 1988). Despite this widespread interest and extensive investigation, the situation today is far from clear as to the exact role of TEM in the maintenance of energy balance, since there are a large number of workers presenting evidence supporting a blunted TEM response in the obese (Kaplan & Leveille, 1976; Pittet *et al.* 1976; Shetty *et al.* 1981; Bessard *et al.* 1983; Den Besten *et al.* 1988) and an equally large number holding a view to the contrary (Bradfield & Jordan, 1973; Felber *et al.* 1981; Blaza & Garrow, 1983; Welle & Campbell, 1983). The ambiguity of these results may well be due to the heterogeneity of subjects, type of test meal, duration of measurement and limitations of the protocols employed. We were, therefore, interested in developing a protocol that would enable us to accurately measure the magnitude, duration and reproducibility of this response. The results reported in the present paper deal with the methodology of TEM measurements and its variation in free-living subjects over extended intervals of time.

MATERIALS AND METHODS

Ten young adult males aged between 19 and 24 years and of body mass index (BMI; weight/height^2 (kg/m^2)) between 18 and 23 were studied. All subjects were recruited after a complete clinical examination. Nutritional status was assessed by anthropometric measurements, i.e. height, weight, mid-upper arm circumference, and skinfolds (using Holtain skinfold callipers, Crymmych, UK). Fat-free mass (FFM) was calculated after estimating percentage body fat from the sum of four skinfolds (biceps, triceps, subscapular,

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and supra-iliac) and applying the formula of Durnin & Womersley (1974). Minute-to-minute oxygen and carbon dioxide concentrations, O_2 consumption, CO_2 production, respiratory quotient (RQ), and energy expenditure (in W) were obtained by using a ventilated-hood system described earlier (Shetty *et al.* 1987). The O_2 and CO_2 analysers were calibrated before the start of each measurement with 100% nitrogen (Indian Oxygen Ltd, Bombay) for zero and CO_2–O_2–N_2 (0·9:20·1:79·0 by vol.; Indian Oxygen Ltd, Bombay) for span. This system had previously been validated against other methods of measurement of O_2 consumption (Soares *et al.* 1989*c*). Calibration using the N_2-infusion technique (Brown *et al.* 1984) yielded a net discrepancy of less than 0·4%. Room temperatures were maintained between 23·5 and 26·5° on all days of the study.

The study was conducted in two parts. The first part consisted of a paired comparison of two different protocols for the measurement of the TEM in five subjects. Protocol 1 measured the TEM response continuously over 6 h, while protocol 2 was designed to reduce the possible effects of restlessness of the subjects over a 6 h measurement period, as in protocol 1. In the second part of the study, in a different group of five subjects, TEM was measured on three separate occasions, using measurement protocol 2, at varying time intervals between measurements (ranging from 1 to 102 d between the first and third measurements). In both studies subjects received the same test meal.

All subjects reported to the laboratory on the evening before the measurement after having completed their evening meal by 19.00 hours. The next morning, after 8 h of sleep and 12 h after the previous evening meal, the subjects were woken at 06.00 hours and allowed 15 min for their toilet. Following a mandatory 45 min rest period, the basal metabolic rate (BMR) was measured for 1 h from 07.00 to 08.00 hours using the ventilated-hood system. Following the BMR measurement, the hood was removed and the subjects were given a standard liquid meal of fixed volume (350 ml). The meal contained 2·5 MJ metabolizable energy with a nutrient composition of (g/kg) protein 100, fat 150 and carbohydrate 750. The meal was ingested over a period of 10 min, after which the hood was replaced and TEM measurements were then made for the next 360 min while the subjects listened to soft music.

Measurement protocol 1 (Fig. 1(a))

After the meal, O_2 consumption was measured continuously for 120 min. The subjects were then allowed a 10 min break, during which the hood was removed and they were allowed to sit up. After the break, the hood was replaced and O_2 consumption was allowed to stabilize, following which it was continuously measured for a further 220 min. Thus, O_2 consumption was measured for 6 h after the meal. During the entire measurement period the subjects lay motionless but awake in the recumbent position.

Measurement protocol 2 (Fig. 1(b))

After ingestion of the meal, O_2 consumption was measured continuously over periods of 60 min each, during the first and sixth hours. During the intervening 4 h, only the initial 30 min in each hour were considered to be the measurement periods representative of the energy expenditure for the entire hour; the remaining 30 min were designated as rest periods. The subject was instructed to lie awake and motionless in the recumbent position during the measurement periods. Between the measurement periods, i.e. during the rest period, they were also asked to lie quietly in bed although a small amount of movement and reading was permitted. At 10 min before the start of each measurement period they were instructed to rest motionless to allow their O_2 consumption to stabilize; 2·5 h after the ingestion of the test meal, during a rest period, the hood was removed and the subjects were permitted to sit up.

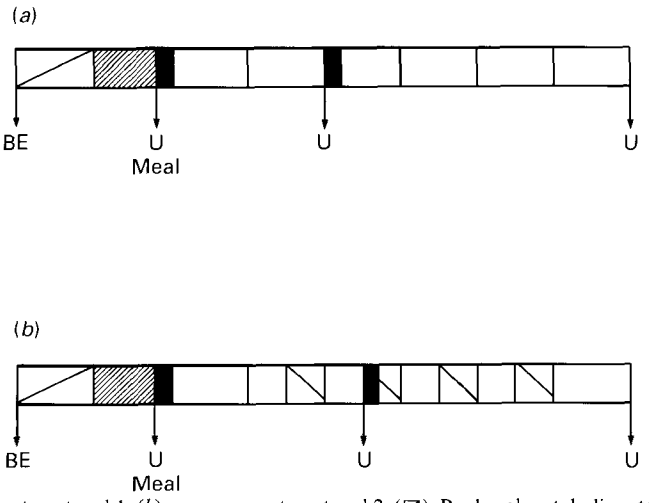

Fig. 1. (*a*) Measurement protocol 1, (*b*) measurement protocol 2. (▨), Pre basal metabolic rate (BMR) rest period; (▨), BMR measurement period; (■), break; (□), thermic effect of meal (TEM) measurement period; (▧), TEM rest period; BE, bladder emptied; U, urine sample.

Urine collection and storage

All subjects were instructed to void soon after waking at 06.00 hours, and again following measurement of BMR, i.e. 2 h later. Urine was also collected 2 h following the meal in protocol 1, 2·5 hours following the meal in protocol 2 and finally at the end of the experiment, i.e. 6 h after the meal in both protocols. On each occasion the void volume was noted and then acidified with concentrated hydrochloric acid. Portions of urine collected over the duration of the BMR and TEM measurements were stored at −20° for the estimation of total urinary N by the micro-Kjeldahl method.

Calculation of BMR, TEM, post-meal total energy output (PMTEO) and substrate oxidation rates (SOR)

BMR was calculated by obtaining the mean energy expenditure over 1 h for each subject. The TEM was considered to have ended when energy expenditures were not significantly different from premeal basal values obtained in either protocol. TEM was calculated by obtaining the mean increment in energy expenditure above premeal basal values during the measurement periods of protocol 2; in the case of protocol 1 the corresponding measurement periods were used for the purpose of comparison. PMTEO was calculated by obtaining the total energy expenditure for the duration of the thermic response following the meal (i.e. TEM + BMR for the duration of the thermic response to the meal).

TEM was also calculated by plotting the mean increment in postprandial energy expenditure obtained for each measurement period *v.* time, while the PMTEO was calculated by plotting the mean postprandial energy expenditures *v.* time, and obtaining the integrated area under the respective curves.

SOR was calculated during the BMR and the postprandial period in each subject for the second part of the study only, using O_2 consumption. CO_2 production rates and total urinary N excretion in each period (Frayn, 1983). No correction was made to the protein oxidation rate to take into account any change in the blood urea pool between the fasted and fed states.

Table 1. *Differences between the two protocols tested† (intermittent and continuous measurements ‡) in normal young adults*

	Subject				
Protocol	A	B	C	D	E
1 BMR (kJ/h)	299·8	315·9	271·0	270·7	271·8
TEM (kJ/6 h)	289·6	200·2	398·2	559·4	205·8
PMTEO (kJ/5 h)*	1749·1	1764·1	1702·3	1686·9	1555·4
PMTEO (kJ/6 h)*	2088·2	2095·4	2024·2	2039·5	1836·9
Wt (kg)	58·0	73·8	64·3	69·5	62·5
FFM (kg)	50·7	55·7	53·6	58·4	51·6
2 BMR (kJ/h)	284·1	307·2	267·2	299·3	244·5
TEM (kJ/5 h)	133·5	155·2	183·9	72·5	202·6
PMTEO (kJ/5 h)	1553·9	1691·3	1519·6	1568·8	1425·1
Wt (kg)	55·6	76·8	64·8	67·8	65·5
FFM (kg)	48·3	56·9	55·2	57·2	53·9

BMR, basal metabolic rate; TEM, thermic effect of meal; PMTEO, post-meal total energy output; FFM, fat-free mass.

* Mean values for protocol 1 were significantly different from those for protocol 2 (paired t test), $P < 0{\cdot}01$.

† For details, see Fig. 1.

‡ For details of procedures, see pp. 166–168.

Statistical analysis

All results were analysed by means of either a paired t test or a two-way analysis of variance (ANOVA) without replicates (Sokal & Rohlf, 1969). Results were considered significant if $P < 0{\cdot}05$. If, in Table 3, between-subjects mean square (MS) is a; between occasions MS is b and error MS is c, then true variance between subjects is $(a-c)$/no. of occasions and true variance between occasions is $(b-c)$/no. of subjects, assuming a non-significant interaction between subject and occasion. The coefficient of variation (CV) was then calculated from the formula:

$$\text{CV}(\%) = (\sqrt{\text{true variance}}/\text{mean}) \times 100 \text{ (Sokal \& Rohlf, 1969).}$$

Ethical approval

Ethical approval was obtained for the study from a duly constituted Human Investigation Committee of the Medical School and all subjects gave fully informed written consent.

RESULTS

The values obtained for TEM were not statistically different when calculated as the sum of the increments in energy expenditure or as the integrated area under the curve obtained by plotting the increments in energy expenditure *v.* time. The results presented here were obtained using the former method of calculation.

Differences between protocols

Postprandial energy expenditure was significantly higher from premeal basal values, even 6 h after the meal in protocol 1, while the TEM response had ended 5 h after the meal in protocol 2. Table 1 gives the differences between protocols 1 and 2. There were no significant differences in body-weight, estimated FFM, BMR and TEM of the subjects between protocols 1 and 2 on paired t tests. However, the mean TEM of the five subjects

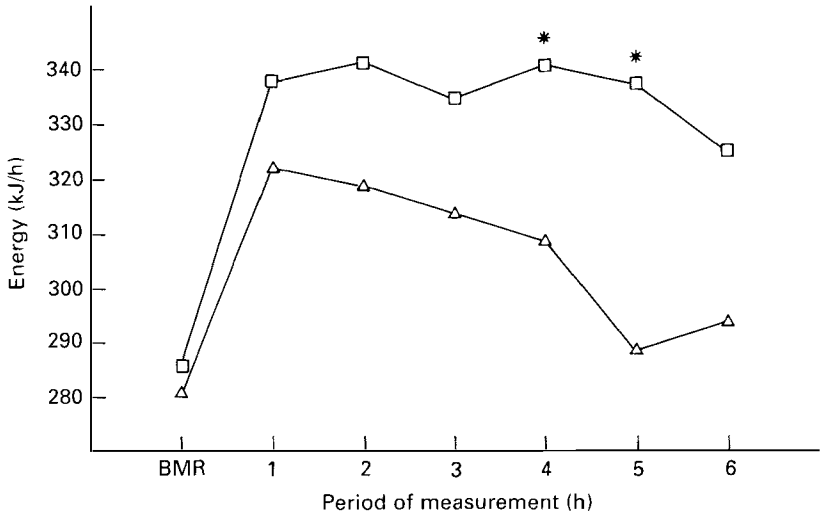

Fig. 2. Thermic effect of a meal measured over 6 h in normal young adult subjects using protocol 1 (□) and protocol 2 (△). For details of protocols, see Fig. 1 and for details of procedures, see pp. 166–168. Points are mean values for five subjects. Mean values were significantly different from those for protocol 2: $*P < 0{\cdot}05$.

Table 2. *Weight, fat-free mass (FFM), basal metabolic rate (BMR), thermic effect of meal (TEM) and post-meal total energy output (PMTEO) of five normal young adult subjects measured on three occasions**

(Mean values with their standard deviations)

	Wt (kg)		FFM (kg)		BMR (kJ/h)		TEM (kJ/6 h)		PMTEO (kJ/6 h)	
Subject	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
F	60·6	0·06	51·7	0·06	269·4	11·15	174·5	76·34	1790·9	11·66
G	61·2	0·17	47·6	0·33	294·6	17·96	141·6	26·18	1908·9	105·52
H	57·9	0·90	49·0	0·35	257·9	25·17	218·5	37·54	1779·3	155·40
I	58·7	0·32	49·8	0·37	250·5	10·88	275·7	61·97	1778·4	19·31
J	71·7	0·17	59·2	0·57	281·0	6·54	198·7	38·73	1891·1	23·18

* For details of procedures, see pp. 165–168.

was 50·5% lower in protocol 2. The increment in energy expenditure, over premeal BMR values, during the fourth and fifth hour following the meal was significantly higher in protocol 1 as compared with protocol 2 (t 3·26, $P < 0{\cdot}05$ and t 4·60, $P < 0{\cdot}01$ respectively; Fig. 2). The PMTEO at 5 h after the meal was higher by 8·3% in protocol 1 compared with protocol 2 (t 6·27, $P < 0{\cdot}01$).

Intra-individual variations in BMR, TEM, PMTEO and SOR

There were no significant differences, between occasions, on an ANOVA of body-weight in the five subjects whose BMR and TEM responses were measured in triplicate. There was a significant difference in estimates of FFM ($P < 0{\cdot}02$); however, the CV was only of the order of 0·68%. The mean BMR and TEM as measured on three occasions are given in Table 2. An ANOVA of the BMR (Table 3) did not reveal any significant differences between measurements in the same subject (CV 2·6%); however, the BMR measured on the

Table 3. *Two-way ANOVA of basal metabolic rate (BMR), thermic effect of meal (TEM) and post-meal total energy output (PMTEO) in five normal young adult subjects*

Source	SS	df	MS	*F*	*P*	CV(%)
BMR						
Between subjects	3749·3	4	937·3	4·7	0·030	5·8
Between occasions	893·6	2	446·8	2·2	NS	2·6
Error	1589·5	8	198·7			
TEM						
Between subjects	30342·0	4	7585·5	6·1	0·015	22·8
Between occasions	16623·1	2	8311·5	6·7	0·019	18·7
Error	9900·8	8	1237·6			
Recalculated TEM using lowest BMR obtained in each subject						
Between subjects	46257·7	4	11564·4	1·9	NS	15·4
Between occasions	17822·1	2	8911·1	1·5	NS	8·6
Error	47706·6	8	5963·3			
PMTEO						
Between subjects	50154·0	4	12538·5	1·9	NS	2·4
Between occasions	19930·9	2	9965·5	1·5	NS	1·4
Error	52731·0	8	6591·4			

SS, sum of squares; MS, mean square; CV, coefficient of variation; NS, not significant.

third occasion was 6·6% lower than the first measurement. When expressed per kg FFM, the true within-subject CV, after separation of measurement error, was of the order of 1·7%. There were significant differences in the TEM on an ANOVA, both between subjects, as well as between occasions (Table 3). The TEM measured on the third occasion was 44·2% higher than that measured on the first occasion. There was a significant inverse correlation ($P < 0·02$) between the BMR and the TEM measured over 2, 3, 4 and 5 h after the meal and also at the end of the response in all five subjects (df 13, r −0·645, −0·647, −0·623, −0·640 and −0·655 respectively). Recalculation of all the TEM in each subject, using the lowest BMR obtained in the same subject, showed no significant differences, either between subjects or between occasions, on an ANOVA (Table 3). The PMTEO were not significantly different between occasions (CV 1·4%) or between subjects (CV 2·4%; Table 3).

SOR of the five subjects studied in triplicate are given in Table 4. ANOVA of carbohydrate and fat oxidation rates, both during the BMR and the TEM measurement, showed no significant variation between subjects or between occasions ($P > 0·05$). An ANOVA of the protein oxidation rates showed significant differences between subjects ($P < 0·05$) but no differences were observed between occasions ($P > 0·05$). There were no significant differences ($P > 0·05$) on an ANOVA, either between subjects or between occasions, in the non-protein RQ obtained during the BMR (0·847 (SE 0·007), CV 1·9%) and TEM (0·924 (SE 0·007), CV 1·9%) measurements.

DISCUSSION

Differences in TEM responses have been evoked to explain, to some extent, the adaptative response to chronic energy deficiency (Shetty, 1980) as well as the aetiology of certain forms of human obesity (Kaplan & Levielle, 1976; Pittet *et al.* 1976; Bessard *et al.* 1983; Den Besten *et al.* 1988). However, before it is suggested that differences in TEM can account for the ease with which some individuals attain energy balance on low energy intakes it is necessary to measure it accurately and establish its variation within individuals.

Table 4. *Intra-individual variation in substrate oxidation rates (SOR) in five normal young adult subjects. Values for basal (B) and postprandial (PP) SOR measured over 1 and 6 h respectively*

(Mean values with their standard deviations)

	Carbohydrate (g)				Fat (g)				Protein (g)			
	B		PP		B		PP		B		PP	
Subject	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
F	7·4	0·8	69·0	14·3	2·9	0·3	11·3	4·4	1·9	0·4	12·8	3·9
G	5·2	1·8	72·6	6·7	2·7	0·8	11·9	4·2	5·3	2·1	14·0	2·9
H	5·6	1·4	54·5	6·2	2·6	1·1	11·0	5·9	3·4	0·3	24·2	1·9
I	7·1	1·0	66·6	1·8	2·0	0·6	8·5	1·2	3·2	0·7	20·7	3·2
J	6·8	1·4	67·5	9·6	3·2	0·9	7·1	4·7	2·4	0·3	27·1	1·7

The thermic response to a test meal depends on its energy density and nutrient composition (Nair *et al.* 1983; Schutz, 1984; Schwartz *et al.* 1985; Belko *et al.* 1986). There are several ways of measuring and expressing TEM (Schutz, 1984). Hence, while measuring or expressing the TEM response one is confronted with the dilemma of administering either a standard meal or glucose load to a subject (Kaplan & Leveille, 1976; Schutz *et al.* 1984; Segal *et al.* 1984, 1990; Swaminathan *et al.* 1985), or a meal whose energy or protein content, or both, is based on body-weight, FFM or percentage ideal body-weight (Shetty *et al.* 1981; Sharief & Macdonald, 1982; Belko *et al.* 1986). Another possible method that has been suggested is to optimize the test meal based on BMR or basal energy expenditure of each individual (Bessard *et al.* 1983; Segal *et al.* 1990). Each of these methods has its advantages and disadvantages. However, most recent studies advocate the use of standard meals (Sjostrom, 1985; Weststrate, 1989); to quote Garrow, 'a log of a given size gives off the same amount of heat in a small or a large oven' (Sims, 1986).

The expression of the TEM response as a percentage of the metabolizable energy in the meal is preferred, in order to avoid reaching erroneous conclusions (Schutz, 1984). This has the distinct advantage that the TEM response is corrected for the energy load administered, in contrast to measuring TEM responses to loads proportional to body size. Hence in the present study the responses of a homogeneous group of young adults to a liquid test meal of 2·5 MJ are presented with the TEM responses being expressed as a percentage of the energy content of the administered test meal.

To reveal the variation in the TEM response in the same subject it would become necessary to administer a standard meal to a homogeneous group of subjects on several occasions. Since differences in the thermic response among individuals or groups could exist in the peak response as well as in the total duration of the response, it also becomes important to evolve a protocol that would fulfil these requirements and enable an investigator to follow the TEM to its termination.

When subjects were measured continuously as in protocol 1, the thermic response was evident even 6 h after the test meal. In comparison, when the same subjects were given the same meal, a 50% lower TEM response was seen in protocol 2 that ended by 5 h instead of 6 h (Table 1). This was reflected in the PMTEO which was significantly higher, by 8·3%, 5 h postprandially in protocol 1. Much of the higher response in protocol 1 could be accounted for by a greater degree of restlessness or fidgeting, which is known to confound

measurement of the TEM (Garrow & Webster, 1984). The observation that the mean energy expenditure in protocol 1 was significantly higher in the fourth and fifth hours would support such a contention, as the contribution from minor physical activity to TEM may be expected to increase with the duration of the experiment. A system of monitoring such physical activity as described by Bessard *et al.* (1983) is useful to evaluate this component while quantifying the contributions made by this variable to the TEM. A possible cause for the large differences between protocols 1 and 2 could be the large within-individual variation in the TEM responses. An earlier study that looked at intra-individual variation of the TEM response in six apparently weight-stable subjects (body-weight being within 2·5 kg of an earlier recording) on two occasions, reported a CV of 28% between occasions in the same individuals (Weststrate, 1989). Therefore the responses of five subjects given the same test meal were examined on three separate occasions in order to validate these observations.

All measurements were made using protocol 2 to reduce the confounding effects of minor physical activity. The results of this part of the study showed a lowering of the BMR by 6·6% on the third occasion, which on an ANOVA showed no significant differences between the three occasions (Table 3). We ascribe these changes to a training effect on BMR that was of a similar magnitude to that previously documented in our laboratory (Soares & Shetty, 1986). The true CV of 2·6% in BMR in the present study was reduced to 1·7% when expressed per kg FFM. This was similar to documented CV for intra-individual variation of BMR (Shetty & Soares, 1988; Soares *et al.* 1989*a*). The TEM responses, however, showed a significant difference between occasions in the same subject and between subjects, even after separating out measurement error (Table 3). The large variation in the TEM response between occasions was evident at any time interval following the meal and, therefore, was not time dependent and unlikely to have been due entirely to restlessness.

Studies on the effect of changes in the preceding day's energy and protein intake have shown little or no effect on the BMR of the next day (Lammert *et al.* 1987; Soares *et al.* 1988). However, the diet consumed during the days before a large carbohydrate test meal (such as in the present study) could have pronounced effects on several interrelated hormonal and metabolic variables, notably postprandial glucose oxidation, glucose storage and, thus, the TEM (Acheson *et al.* 1984). These effects are, however, excluded since we have earlier found habitual carbohydrate intakes in a similar group of subjects to be > 350 g/d (Soares *et al.* 1989*a*). Therefore, available body stores of carbohydrate were likely to be replete in these subjects, and the observed variations within individuals were unlikely to have been due to a different metabolic fate of the test meal on each occasion. This is further confirmed by the lack of any differences in the rates of carbohydrate and fat oxidation both between occasions and between subjects. The non-significance of differences in the carbohydrate and fat SOR may also be attributed to the small size (n 5). However, in the light of the non-significant differences in the PMTEO measurements, they are more likely to be biological rather than statistical. Apparent differences in protein oxidation rates between subjects cannot be discussed, since oxidation rates have not been corrected for changes in the plasma urea pool from the fasted to the fed state.

It has been reported that there is a circadian variation in basal O_2 consumption (Ashoff & Pohl, 1970) that can amount to 25% of the mean value for the day (Noack *et al.* 1984). Such a variation in the baseline could contribute to the variation in the TEM, since calculations of TEM are based on the premise that the baseline, i.e. the BMR, is stable throughout the measurement period. In the present study the TEM responses increased as the baseline over which it was calculated decreased, such that the BMR and TEM were significantly negatively correlated over the three occasions they were measured. When

changes in BMR are reciprocal to those in TEM, then the variation in the PMTEO should be non-significant from occasion to occasion in each subject. However, if there is a component of 'true' variation in TEM then it should also be reflected in the PMTEO. An analysis of the PMTEO by ANOVA (Table 3) showed non-significant differences between occasions within the same subject (CV 1·4%, $P > 0·05$) suggesting that the inherent variation of TEM in each subject may well be smaller than the observed variation (Table 3). Therefore the TEM for each occasion was recalculated using the lowest BMR obtained in each subject. This in effect eliminated the contribution of an altered baseline to the total variation in the TEM from occasion to occasion in each subject. An ANOVA of the recalculated TEM responses showed no significant differences between occasions in the same subject or between subjects (Table 3). The CV for between-occasions within-subject variation was reduced to 8·6% compared with the CV of 18·7% obtained by direct computation of TEM using the baseline recorded for the day. Apparently the baseline BMR over which the increment in energy expenditure is calculated now takes on additional significance as it may have a confounding effect on the TEM measured on the same day. Hence, it may be necessary to ensure that the BMR recorded is the lowest for each subject by earlier familiarization with the measurement system and with the protocol used for measurement of the TEM. This CV of 8·6% is lower than the value of (CV 28%) reported by Weststrate (1989) for intra-individual variation in TEM. In part, this large CV reported by Weststrate (1989) could be due to the measurement protocol used (continuous 4 h measurements with subjects watching films). An interesting aspect of our study was the significant negative correlation between BMR and TEM when subjects were measured repeatedly. The non-significant differences in PMTEO between occasions in the same subject, as well as between subjects, would support our earlier contention that the PMTEO is a useful measurement for assessing the overall thermic response to a meal (Soares *et al.* 1989*b*).

In conclusion, the present study has demonstrated that, on including appropriate rest periods during measurements of TEM, it is possible to follow the TEM response to its termination. Such a protocol would enable the assessment of TEM differences not only in the peak response but also in the duration and hence magnitude of the response. Small changes in BMR from occasion to occasion affected the variation in TEM measurements in the same subject. It may, hence, be necessary to ensure the lowest baseline in each subject, in order to reduce the intra-individual variation in TEM. However, even on accounting for baseline changes, there was a residual variation (within-subject between-occasion) of 8·6% in the TEM which was still sizeable, though not statistically significant. Future studies designed to look for differences in TEM among groups must take this variation into account by the use of appropriate sample sizes. The relative constancy of PMTEO measurements within individuals suggests its usefulness for revealing differences in the thermic response to a meal in the same individual following intervention of any kind (dietary, pharmacological or physical), and among groups when adjusted for differences in body size.

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