Factors influencing the composition of the weight lost by obese patients on a reducing diet

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1. Weight loss, resting metabolic rate and nitrogen loss were measured in forty obese inpatients on reducing diets.

2. Five subjects ate 3·55 MJ/d for 6 weeks (Expt 1). Twenty-one subjects ate 4·2 MJ/d for the first week, 2·0 MJ/d for the second week and 4·2 MJ/d for the third week (Expt 2). Fourteen subjects ate 3·4 MJ/d for the first week and then 0·87 MJ protein or carbohydrate for the second or third weeks, using a cross-over design for alternate patients (Expt 3).

3. Patients in Expt 1 had highest weight loss and N loss in the first 2 weeks, but adapted to the energy restriction over the remaining weeks. On average subjects were in N balance at the end of the study.

4. In Expt 2 patients eating 2·0 MJ/d in week 2 showed increased weight loss compared with week 1. N loss was not raised but it failed to decrease as it had in Expt 1. Weight loss and N loss were reduced on return to 4·2 MJ/d for a third week.

5. In Expt 3 patients eating 0·87 MJ protein showed significantly more weight loss and less N loss than patients eating 0·87 MJ carbohydrate.

6. Resting metabolic rate decreased with time on the low-energy diet, but the manipulations of energy or protein content did not significantly affect the pattern of decrease.

7. Both weight loss and N loss were greater the lower the energy intake, and both decreased with time. Diets with a high protein:energy value give a favourable value for N:weight loss at each level of energy intake.

If the energy intake of an obese patient is reduced below the level of energy expenditure the energy stores of the body must decrease, and this is usually reflected in a decrease in body-weight. The obese person has too high a fat:lean tissue value, so it is desirable that the weight loss should be mainly at the expense of fat. Since fat loss is a slow process, such patients yearn for treatment which will produce rapid weight loss. This can be achieved by treatments which cause the loss of water or lean tissue which are attractive to the patient in the short term, but only make matters worse in the long run. Resting metabolic rate (RMR) is the factor which chiefly determines how quickly obese patients can lose weight (Garrow *et al.* 1978) and this in turn is most closely related to lean body mass (Halliday *et al.* 1979) so treatment which causes excessive loss of lean tissue is self-defeating in the end.

Apfelbaum and his colleagues (Apfelbaum *et al.* 1967) reported that obese patients who had 55 g casein daily as the only energy source maintained nitrogen balance. Since then there have been many versions of the 'protein-sparing modified fast' (Blackburn *et al.* 1973; Baird *et al.* 1974; Genuth *et al.* 1974; Bistrian *et al.* 1977; Howard & Baird, 1977; Wilson & Lamberts, 1979) in which attempts were made to achieve rapid fat loss without loss of lean tissue by giving diets with very low energy (approximately 2 MJ/d) but high protein (30–120 g/d) and varying amounts of carbohydrate.

Calloway & Spector (1954) made a comprehensive review of the effect of restricted energy and protein intake on N balance, and concluded that active young men in negative energy balance would inevitably be in negative nitrogen balance whatever the protein intake.

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Table 1. *Details of subjects*

(Mean values and standard deviations; ranges in parentheses)

Expt no.	No. of subjects	Age (years) Mean SD	Wt (kg) Mean SD	Obesity index* (kg/m²) Mean SD
1	5	31 9 (19–41)	107·5 24·0 (80·5–135·2)	38·2 4·8 (30·9–43·9)
2	21	37 11 (17–56)	88·2 16·8 (63·8–121·3)	34·8 7·3 (24·5–47·1)
3	14	40 15 (16–67)	97·8 21·2 (67·2–119·0)	36·1 7·4 (23·5–48·1)
Mean:	40	38 13 (16–67)	94·1 19·7 (63·8–135·2)	35·8 7·1 (24·5–48·1)

* Obesity index = W/H^2 where W is body-weight (kg) and H is height (m).

However this generalization does not necessarily apply to obese patients, since with total starvation obese people are more efficient at conserving N than lean people (van Itallie & Yang, 1977; Forbes & Drenick, 1979), and even lean subjects become progressively more efficient with prolonged semistarvation (Keys *et al.* 1950). We have therefore studied weight loss, N balance and metabolic rate of obese patients under very carefully controlled conditions in a metabolic ward (Garrow *et al.* 1978), and the influence on these factors of the duration of the diet (3–6 weeks), the energy content (0·8, 2·0, 3·4 or 4·2 MJ), the percentage of energy supplied by protein (2, 12, 20 or 85 %), the effect of the diet in the previous week, the stage of the menstrual cycle, and the fat content of the patient.

EXPERIMENTAL

Subjects

Subjects were recruited from a hospital outpatient clinic to which they had been referred by their family practitioner. If they failed to lose weight or maintain weight within the desirable range under outpatient supervision they were offered a place in a metabolic unit where they were guaranteed to lose weight. The experimental protocol and strict supervision whilst in the unit were explained to subjects before admission and also in the presence of a senior nurse after admission. Patient consent was obtained before any tests were performed. The procedures had been approved by the Northwick Park Hospital Ethical Committee.

A total of forty subjects were used in these trials, thirty-eight were female and two were male. Subjects were allocated to the current trial at the time of admission. Analysis of the age, weight and obesity index for subjects on the different trials revealed no differences between groups (Table 1).

Research unit

The unit accommodates a maximum of three subjects in one single-bedded and one two-bedded room. Leisure facilities are provided in a day room. The unit occupies the end of a research paediatric ward which is staffed by personnel trained in metabolic work. Patients are not allowed to leave the unit at any time unless accompanied by a member of staff. Visitors enter at the far end of the children's ward and are not allowed to take bags or outdoor clothing into the unit. This system ensures that patients have access to no food other than that provided from the diet kitchen.

Table 2. *Protein (g) and energy (MJ) contents of experimental diets*

Expt no.		Week of experiment 1	2	3	4–6
1	Protein	43	45	45	45
	Energy	3·55	3·55	3·55	3·55
	% Protein-energy	20	21	21	21
		1	2	3	
2	Protein	31	23	30	
	Energy	4·2	2·0	4·2	
	% Protein-energy	12	19	12	
		1	2		3
			Protein	Carbohydrate	Protein	Carbohydrate
3	Protein	41	44	1	44	1
	Energy	3·4	0·87	0·87	0·87	0·87
	% Protein-energy	20	85	2	85	2

Food

Food is prepared and served, and uneaten food is weighed back by trained metabolic cooks from the diet kitchen on the paediatric ward. Patients are encouraged to eat all the food served at the specified meal times. Subjects eating less than 75 % of their food allowance were excluded from the study.

Food used in the studies was homogenous in texture so that any food left was of the same composition as that eaten. A range of foods (e.g. milkshakes, fruit juice, soup, jelly, mousse and sandwiches with spreads) was developed. Foods were also adapted so that each type could vary in energy density over a threefold range without noticeable changes in taste or texture (Garrow *et al.* 1978).

The food ingredients were bought in bulk at the outset of the trials. Energy content was determined by bomb calorimetry and N content by Kjeldahl analysis: dietary intakes were calculated using a computer program. Since milk or egg was the main source of protein in all the diets, the biological value of the protein was high. Samples of food served to patients were taken at intervals and analysed in order to check that food was correctly prepared.

Food was served three times daily, breakfast 09.00–10.00 hours; lunch 12.45–13.45 hours; dinner 18.45–19.45 hours. Small milk allowances were served mid-morning 10.30 hours; mid-afternoon 15.30 hours and evening 22.00 hours. Patients were allowed *ad lib.* access to energy-free fluids. They recorded intake (units cups) and coffee intake on charts provided.

Treatment protocols

Admission was on Wednesdays between 10.00–16.00 hours. Day 1 was an incomplete day (i.e. less than 24 h) and was excluded from all analyses. Day 2 began with a fast from 00.00–18.45 hours but the evening meal allowance was adjusted to normal levels for the week. Week 1 values were mean of 6 d. Values for other treatment weeks were means of 7 d.

Expt 1 (3·55 *MJ* (850 *kcal*) *for* 6 *weeks*). Six patients were given 3·55 MJ (850 kcal) homogenous food/d for a 6 week (43 d) stay. The protein content of the diet was 45 g/d or 21 % energy from protein.

Expt 2 (4·2, 2·0 and 4·2 *MJ for weeks* 1, 2 *and* 3 *respectively*). Twenty-one patients were given 4·2 MJ (1000 kcal)/d for the first week, 2·0 MJ (500 kcal)/d for the second week, and 4·2 MJ (1000 kcal)/d for the last week of their 3-week stay. They were unaware of the change in the energy content of their food as the volume of food was the same. Absolute

protein intake was held as constant as possible using the experimental food but in terms of % energy from protein this was raised for week 2 (see Table 2).

Expt 3 (3·4 *MJ for week* 1, *then* 0·87 *MJ protein or carbohydrate on week* 2 *or* 3). Fourteen patients were given 3·4 MJ (800 kcal)/d for the first week of a 3-week stay. They received 0·87 MJ (200 kcal)/d in the second and third weeks. In one of the weeks the food was all protein (scrambled egg-whites or casein-based drinks). In the other week the food was all carbohydrate (cornflour desserts or glucose-polymer drinks). The protein intake was held constant over week 1 and the protein week (see Table 2). Treatment order was alternated for weeks 2 and 3 for each patient in order to compensate for any sequence effects during those 2 weeks. Two of the subjects in this study were male and so they were allocated one to each sequence.

Measurements on patients

The height (m) of each patient was measured on admission to the unit. Body-weight (kg) was measured with an accuracy of ± 50 g each week-day using a beam balance. The balance had a variable zero so the patient was unaware of her weight change. Patients wore light cotton suits of standard weight and were weighed fasting and having voided urine. Rate of weight loss was calculated in g/d for each treatment week.

Obesity index (weight:height^2; W/H^2) was calculated using body-weight on day 2.

Body fat was measured indirectly from total body potassium. Total body K was measured by counting the radiation from natural ^{40}K (Smith *et al.* 1979). It was assumed that the fat-free tissue of women contains 60 mmol K/kg (Boddy *et al.* 1976). Body fat was derived by subtracting fat-free weight from total body-weight.

N output was measured from 24 h daily urine and stool collections. A 1 % sample of each daily output of urine was pooled for each treatment week and weekly samples analysed. Stool samples were frozen in 7 d batches. They were thawed, made up to a known weight with distilled water, homogenized and portions analysed. All analyses were done in duplicate by routine Kjeldahl analysis. N balance was derived by subtracting N output (urine+stool) from N input (see p. 277). Skin, blood and menstrual losses were not measured. Subjects were in negative N balance most of the time so the results are expressed as N loss (g/d), averaged for each test week.

Fasting RMR was measured using a ventilated-hood system of indirect calorimetry as previously described (Garrow & Hawes, 1972). Measurements were made between 08.00–09.30 hours on days 2, 3 and 7 or 8 during week 1. The mean of these three readings was used as the week 1 value. RMR was measured subsequently at the end of each test week. Mean values for each test week were derived by averaging the two values at the outset and end of each test week.

RESULTS

Expt 1 (*Constant diet:* 3·55 *MJ* (850 *kcal*) *for* 6 *weeks*)

Table 3a gives mean weight loss and N loss of the five subjects eating 3·5 MJ (850 kcal)/d for 43 d. Weight loss was greatest in the first week and fell for remaining weeks. N loss was also highest in week 1 (3·03 g/d) and decreased during the subsequent weeks. In week 6 three patients were in positive N balance and the mean of −0·09 g/d implied a very small N gain by the group as a whole. However this mean concealed a wide range of differences as shown in Table 4.

Table 4 gives detailed results of this experiment: the subjects are arranged in descending order of body-weight. When individual results were examined there were considerable fluctuations from week to week in N balance and rate of weight loss, even under constant

Table 3. *Expts* 1–3. *Summary of the average daily loss of nitrogen* (*g*), *body-weight* (*g*), *and N loss: weight loss* (*g N/kg body-weight*), *in each week of the experiment*

Expt no.	No. of subjects		Week of experiment					
			1	2	3	4	5	6
1	5	N loss (g)	3·03	2·04	1·48	0·58	1·53	−0·09
		Wt loss (g)	350	229	193	200	273	183
		N loss: wt loss (g N/kg)	8·7	8·9	7·7	2·9	5·6	−0·5
			1	2	3			
2	21	N loss (g) Mean	2·46	2·08	0·90			
		SD	1·29	1·22	1·23			
		Wt loss (g) Mean	239	304	114			
		SD	93	88	67			
		N loss: wt loss (g N/kg)	10·3	6·8	7·9			
			1	2		3		
				Protein	Carbo-hydrate	Protein	Carbo-hydrate	
3	14	N loss (g)	2·7	4·9	6·1	2·6	4·6	
		Wt loss (g)	370	602	481	283	159	
		N loss: wt loss (g N/kg)	7·4	8·1	12·7	9·2	28·9	

experimental conditions. Subject TL was in positive N balance during weeks 4 and 6, but in negative balance in week 5. This might be attributed to the beginning of the menstrual cycle in week 5. The values for stool N and urine creatinine were included in Table 4 because apparent fluctuations in N balance might have arisen from incomplete urine collection or variations in faecal N loss. Neither of these explanations was convincing, since in all the patients urine creatinine was fairly constant, confirming the completeness of urine collections. Although stool N varied from week to week this does not explain the inconstancy of the N balance results. We must conclude, therefore, that N balance fluctuated from week to week, even under constant dietary conditions, and that there seemed to be a tendency for N balance to be more negative, and for weight loss to be greater, during the early part of the menstrual cycle.

The average RMR for the subjects in Expt 1 were 273, 253, 246, 245, 242 and 244 ml oxygen/min for weeks 1–6 respectively. Two way analysis of variance showed significant differences between patients $F(4, 20)$ 170·0, $P < 0{\cdot}001$ and between weeks $F(5, 20)$ 7·1, $P < 0{\cdot}001$. Contrasts were used to compare the means of each week. The decrease in RMR between weeks 1 and 2 was significant (t 3·2, $P < 0{\cdot}01$) but there was no significant change in RMR in subsequent weeks.

Expt 2 (4·2, 2·0 *and* 4·2 *MJ/d for weeks* 1, 2 *and* 3)

Table 3b shows mean weight loss and N loss of the twenty-one subjects in this study. Weight loss was highest on 2·0 MJ/d in week 2. The results were analysed using the Student's paired t test. This weight loss was significantly greater than that achieved in week 1 when the intake was 4·2 MJ ($P < 0{\cdot}05$). Weight loss was least in week 3 when energy intake was raised from 2·0 to 4·2 MJ/d. This rate of weight loss was significantly less than either week 1 or 2 ($P < 0{\cdot}001$).

N loss was highest in weeks 1 and 2: there was no significant decrease in N loss (t 1·44, n.s.) between week 1 and 2 as there had been in Expt 1 when energy intake was constant. The N loss in week 2 of Expt 2 remained at 2 g/d when energy intake is halved, so the reduction in energy intake prevented the adaptive conservation of N. In week 3 when energy intake was doubled N loss was halved which was a significant reduction ($P < 0{\cdot}01$).

Table 4. *Resting metabolic rate (RMR; ml oxygen/min), nitrogen balance (g), weight loss (kg) and creatinine excretion (mmol) in five obese women given 3·4 MJ (800 kcal) daily for 6 weeks*

Subject	Age (years)	Wt (kg)	LBM (kg)	Fat (kg)	Week no.	RMR	Intake (/week) Energy (MJ)	Intake (/week) N (g)	N output (g/week) Urine	N output (g/week) Stool	N balance (g)	Wt loss (kg)	Daily urine creatinine Mean	Daily urine creatinine SD
PH	19	135·2	65·9	69·3	1*	352	18·6	37·9	59·1	—†	−21·2	2·50	11·8	2·9
					2	335	25·0	50·6	56·3	3·5	− 9·2	1·70	14·5	0·6
					3	321	24·8	49·4	68·6	—	−19·2	1·70	13·8	0·4
					4‡	314	24·8	49·6	56·3	—	− 6·7	1·60	12·4	1·3
					5	304	24·0	48·2	56·2	4·0	−12·0	2·70	11·9	2·1
					6	302	24·6	50·2	46·7	2·3	+ 1·2	1·58	12·0	0·7
				Total							−67·1	11·78		
BM	41	129·6	60·5	69·1	1	313	19·6	40·4	63·6	—	−23·2	3·75	14·8	0·9
					2	261	25·0	53·0	74·2	—	−21·2	2·05	14·2	2·0
					3	267	25·0	53·3	70·5	2·2	−19·4	1·01	14·0	0·3
					4	282	25·1	53·5	67·3	2·9	−16·8	2·09	14·7	0·2
					5	271	25·3	54·4	63·1	3·7	−12·4	1·61	13·1	0·5
					6	285	25·3	54·4	60·4	1·6	− 7·6	1·79	12·8	0·8
				Total							−100·6	12·30		
MW	34	101·5	56·5	45·0	1‡	266	20·5	36·5	54·3	4·6	−22·4	2·74	14·4	0·5
					2	259	25·1	51·3	61·7	3·3	−13·7	1·51	13·5	0·5
					3	243	25·1	51·3	59·2	5·7	−13·7	1·30	12·8	1·0
					4	237	25·0	51·2	61·4	—	−10·2	1·05	12·0	4·2
					5‡	246	24·9	51·0	56·2	3·3	− 8·5	1·20	12·7	2·4
					6	248	25·0	51·2	58·3	3·2	−10·3	2·10	13·1	0·4
				Total							−78·8	9·90		
TL	34	90·6	41·3	49·3	1	207	19·4	38·4	50·0	—	−11·7	0·85	12·5	0·6
					2‡	198	22·6	44·7	44·2	3·5	− 3·1	1·70	11·8	1·0
					3	196	21·2	41·6	45·5	—	− 3·9	1·65	10·7	1·0
					4	197	23·7	47·5	32·8	—	+14·7	0·19	9·8	2·3
					5‡	186	23·4	46·4	52·4	3·8	− 9·8	0·97	10·3	1·5
					6	196	22·1	44·3	24·3	2·6	+17·4	1·50	10·6	1·4
				Total							+ 3·6	6·86		
MP	26	80·5	46·5	34·0	1‡	227	20·1	41·6	54·0	—	−12·4	0·65	12·1	0·2
					2	213	25·1	54·6	78·8	—	−24·2	1·05	12·8	0·3
					3	205	24·7	52·0	41·9	5·7	+ 4·4	1·10	14·3	0·8
					4	196	22·6	49·4	50·5	—	− 1·1	2·05	10·4	0·7
					5‡	203	18·3	37·1	46·7	1·4	−10·9	3·06	10·8	1·2
					6	189	20·5	41·6	37·5	1·7	+ 2·4	0·51	10·3	0·4
				Total							−41·8	8·42		

LBM, lean body mass.
* Week 1 included only 6 balance days.
† Where no value is given no stool was passed during the week.
‡ A menstrual period started during that week.

The twenty-one subjects showed a decrease in RMR from 252 ± 30 ml O_2/min in the first week to 236 ± 27 in the second week and a further decrease to 224 ± 26 ml O_2/min in the third week. RMR was highest in week 1 and decreased significantly ($P < 0.001$) in week 2 when intake was decreased. This trend was similar to the sequential effect observed in Expt 1 and so this result could be predicted owing to the effect of time rather than the specific change in diet. RMR stayed lower in week 3 than in week 1 ($P < 0.001$) showing that the effect of a twofold increase in energy intake did not significantly change RMR. Thus the primary influence on RMR is the duration of the reduced energy intake. These different levels of low energy intake had no discernible effect on RMR over this time period.

Expt 3 (3·4 *MJ/d for week* 1, *with* 0·87 *MJ/d of either protein or carbohydrate in week* 2 *and* 3) The fourteen subjects in this study were all given 3·4 MJ and 41 g protein daily for the first week, and then 0·87 MJ daily for the second and third weeks. Half the subjects had virtually pure protein in the second week and virtually pure carbohydrate in the third week, and the other half had similar diets but in the reverse order in weeks 2 and 3. The effects on weight loss, N loss and RMR are summarized in Table 5. The results for weeks 2 and 3 were

Table 5. *Expt* 3. *Weight loss* (*g/d*), *nitrogen loss* (*g/d*) *and resting metabolic rate* (*RMR, ml oxygen/min*) *in fourteen subjects given* 3·4 *MJ for week* 1 *followed by* 2·87 *MJ protein or carbohydrate daily for weeks* 2 *and* 3

	Week of experiment				
	1	2	3	Protein	Carbohydrate
Wt loss	370	541	266****	422	333**
	198	166	158	239	205
N loss	2·74	5·48	3·62***	3·83**	5·40
	2·28	1·74	1·66	1·88	1·66
RMR	283	257	244*	252	248
	56	44	46	42	49

Values were statistically significant: *$P < 0.05$, **$P < 0.02$, ***$P < 0.01$, ****$P < 0.001$.

analysed by Student's paired t test appropriate for cross-over designs: the t values were calculated as the mean differences in values for the two weeks (sequence effect) and for the two diets (diet effect) divided by the standard error of the mean differences.

Weight loss was highest in the second week when energy intake was decreased from 3·4 to 0·87 MJ. Weight loss was significantly lower in week 3 ($P < 0.001$) when adaptation to the 0·87 MJ intake had occurred. Weeks 2 and 3 analysed for diet showed that there was significantly more weight loss during the protein week than during the carbohydrate week ($P < 0.02$).

N loss in week 1 was similar in magnitude to the N losses for the first week of the other trials. N loss was greatest in week 2 when there is a 75 % reduction in energy intake. This confirmed the finding of Expt 2 that N loss can be increased by reducing the energy content of the diet. Week 3 N losses were significantly less than those in week 2 ($P < 0.01$). This again confirmed the effect of time on reducing N loss even when energy intakes were as low as 0·87 MJ/d. The effect of 0·87 MJ as protein rather than as carbohydrate was to reduce N loss ($P < 0.02$) which demonstrated the N-sparing effect of protein in the diet.

As in the previous studies, RMR was highest during the first week. The subjects in Expt 3 had the highest mean RMR of any group and this accounted for the highest weight loss in the first week. A significant decrease in RMR was not observed until week 3. There were no differences in RMR with the two test diets. In all three experiments the effect of the low-energy diet on RMR was to cause a decrease over the first 3 weeks, with little effect thereafter. The manipulations of the energy or protein content of the diet had no demonstrable effect on this decreasing trend in metabolic rate.

Expts 1–3 N loss: Weight loss

More interesting effects were observed concerning the rate of weight loss and that of N loss: these results are summarized for Expts 1–3 in Table 3. In general, when weight loss was rapid, N was also lost rapidly, so it was of interest to calculate the N loss:weight loss value for each week on each diet. Ideally this value should be as low as possible, since this implies that fat, and not lean tissue, was being lost.

In Expt 1 there was a trend towards reduction in N loss:weight loss values with successive weeks on the diet. The group started with a value of 8·7 g/kg, which decreased by week 6 to a very slightly negative value (N gain with weight loss). The main deviation from this trend was in week 5, when the value increased to 5·6 g/kg, probably due to menstruation by three of the subjects.

In Expt 3, week 1, the value for N loss:weight loss was similar to that found in Expt 1, week 1. In the second and third weeks of Expt 3 those subjects who received 0·87 MJ mainly as protein showed a more favourable N loss:weight loss value than those who received 0·87 MJ carbohydrate.

In Expt 2, week 1, the diet provided only 12% protein-energy, compared with 20% protein-energy in the other two trials. The N loss:weight loss value was correspondingly higher at 10·3 g/kg, compared with 8·7 and 7·4 in Expts 1 and 3 respectively. The value improved in the second week of Expt 2, despite the decrease in energy intake to 2·0 MJ, since the protein-energy in that week was increased from 12 to 19%. In week 3 the value deteriorated to 7·9 g/kg, contrary to the trend with time, because the protein-energy was decreased from 19 to 12%.

In total starvation the N loss:weight loss value is inversely related to total body fat stores (Forbes & Drenick, 1979). To see if this effect could be demonstrated in our subjects on low energy diets the total N loss/kg body-weight loss for each subject in Expt 2 was plotted *v.* that subject's total body fat: the result is shown in Fig. 1. There was a large scatter, but a significant negative correlation ($P < 0.05$) was found between total fat and N/kg weight loss.

DISCUSSION

Before drawing conclusions about the effect of the duration or composition of a reducing diet on the weight loss, it is necessary to consider the implications of the results presented in Table 4. Among the five subjects in this series one finished the 6-week study slightly in positive N balance, while another had lost more than 100 g N. It was very unlikely that experimental error contributed much to the inter-individual variations: in another study (Garrow *et al.* 1979) we have found that N balance in our metabolic ward is a very consistent measurement when checked against other methods. The best we could do, therefore, was to make measurements on groups of subjects, and bear in mind the fact that, even if the average N balance for the group was not significantly different from zero, this did not mean that every member of the group was virtually in N balance. Furthermore, differences between diets which can be demonstrated over a one-week period do not necessarily persist over larger periods.

The N-sparing effect of a reducing diet was influenced by at least five factors, which should be considered when the properties of such diets are compared.

(*a*) *Duration.* In each experiment shown in Table 3 the N loss decreased with time. This effect was most clearly seen in Expt 1, since there were no changes in diet during the 6 weeks to obscure the effect of time. The group of patients were on average losing 3·03 g N/d during the first week, but were in N balance by the end of the 6-week trial. It was therefore important, when two diets were compared for their protein-sparing effect, that they should be

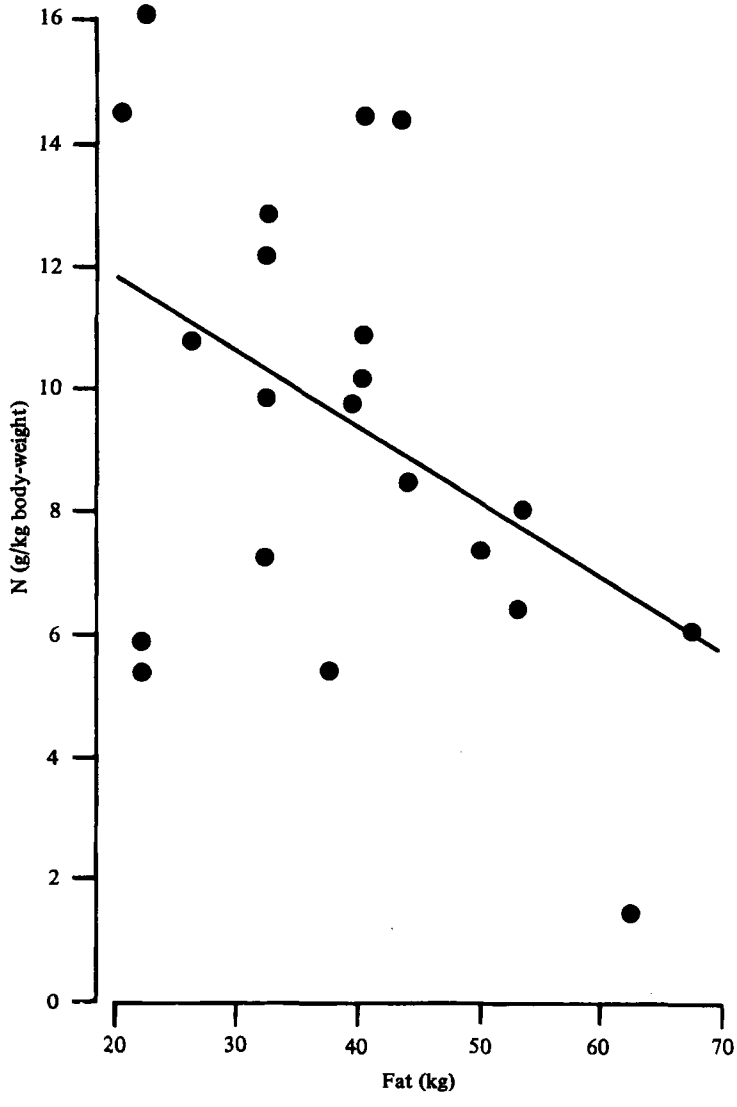

Fig. 1. Relationship between body fat (kg) and nitrogen loss:weight loss (g N/kg body-weight) in twenty-one obese women having a diet supplying 3·4 MJ/d for 3 weeks.

given over the same time period, using a balanced cross-over design such as that in Expt 3. The longer the subjects had been on a restricted diet, the easier it was to achieve N balance, and a diet given after a period of severe restriction would appear to be more effective in protein-sparing than when the same diet was tested immediately after a period of *ad lib.* feeding.

(*b*) *Energy intake.* The lower the energy intake (other things being equal) the greater the weight loss and N loss. The results in Table 3 showed that weight loss and N loss did not necessarily increase proportionately: in Expt 2 when the energy intake was decreased from 4·2 MJ to 2·0 MJ weight loss increased more than N loss, so the N loss:weight loss value

(g N/kg weight loss) improved from 10·3 to 6·8 between the first and second week. This improvement was not remarkable, since it would be predicted from the time-effect mentioned previously. However, in week 3 of Expt 2, when the energy intake was increased again to 4·2 MJ, the N loss:weight loss value became worse, at 7·9 g N/kg weight loss, which was contrary to the expected trend with time.

However, reducing the energy intake still more severely did not further improve the N loss:weight loss value, as can be seen from the results of Expt 3. During week 1, when energy was 3·4 MJ, with 41 g protein, both weight loss and N loss were similar to that observed in Expt 1, week 1, when a similar diet was given. In weeks 2 and 3 of Expt 3, however, when the energy intake was reduced to 0·87 MJ, the N loss:weight loss value became worse, even with the protein diet.

(*c*) *Proportion of energy as protein.* In Expt 2 the N loss:weight loss value is only 6·8 in week 2 and 7·9 in week 3, despite the previous statements that N conservation should improve with time, and be better on a higher energy intake. This was explained by the high protein concentration (19 % protein-energy) in the low-energy diet in week 2. In Expt 3 N loss was significantly less in week 3 compared with week 2 (the sequence effect mentioned previously), but when the 'protein' and 'carbohydrate' weeks were compared, in a cross-over design which allowed for the sequence effect, the loss of N was significantly less with the protein diet (3·83 g N/d) than with the carbohydrate diet (5·40 g N/d: $P < 0{\cdot}02$). Thus, even at very low energy intakes (2·0 or 0·87 MJ) the provision of a high concentration of dietary protein reduced N loss. This is contrary to the conclusions of Calloway & Spector (1954).

(*d*) *Fat stores.* The results in Fig. 1 suggested that on a mean intake of approximately 3·4 MJ/d for 3 weeks the N loss:weight loss was inversely related to the fat stores of the patient. This effect has been shown previously for patients on total starvation (Forbes & Drenick, 1979).

(*e*) *Previous diet.* It is a corollary to the first factor (concerning the duration of the diet) that the results obtained in the first week of an N balance study may be affected by the previous *ad lib.* diet of the subjects. We observed greater variability during the first week of balance studies than during subsequent weeks, and this may have been due to differences in the patients' diets before coming in to hospital.

An important attribute of a reducing diet for obese patients was that it should be acceptable. Although other workers have reported that a diet providing only 0·87 MJ/d, as protein, was well tolerated by patients this was not our experience, and the protocol of Expt 3 was by far the most difficult to complete because patients became nauseated and unable to take 44 g protein as virtually their only energy source. For this reason, and also because it did not produce a particularly favourable N loss:weight loss value, this regimen did not seem suitable for the management of obesity.

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