Comparison of high-fat and high-carbohydrate foods in a meal or snack on short-term fat and energy intakes in obese women*

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The present study aimed to compare the action of high-fat and high-carbohydrate (CHO) foods on meal size (satiation) and post-meal satiety in obese women. A within-subjects design was used; each participant received all four nutritional challenges. Fifteen healthy obese women (age 21–56 years, BMI 35–48 kg/m^2) participated; thirteen completed all four test days. On two test days, participants were exposed to a nutritional challenge comprising an *ad libitum* high-fat or high-CHO lunch. On the other two test days they were exposed to a challenge comprising an *ad libitum* sweet high-fat or high-CHO mid-afternoon snack. Energy and macronutrient intakes were measured at each eating episode. Visual analogue rating scales were completed periodically to record subjective feelings of appetite. When offered a high-CHO selection of foods at lunch and mid-afternoon participants consumed less energy than when offered a high-fat selection. However, post-meal satiety was similar. Total test-day energy intake was significantly higher when high-fat foods were consumed at lunch, but not as a snack. Consumption of high-fat foods at a lunch and snack increased the amount of fat consumed over the whole test day. In conclusion, energy intake of an eating episode was influenced by nutrient composition in this group of obese women. Consumption of high-fat foods at lunch or as a snack led to overconsumption relative to high-CHO foods. However, high-fat foods at meals may have greater potential to influence daily intake than at snacks, probably because meals are larger eating episodes and therefore give greater opportunity to overconsume.

High-fat: High-carbohydrate: Energy intake: Appetite control

There is considerable evidence that weight gain and obesity are associated with the amount of dietary fat consumed (Golay & Bobbioni, 1997). The prevalence of obesity is greater amongst habitual high-fat consumers (Macdiarmid *et al.* 1996). Further, high-fat diets have been shown to promote weight gain (Lissner *et al.* 1987). The weight gain on high-fat diets may be particularly marked in women who have a genetic predisposition to obesity (Heitmann *et al.* 1995). There is some evidence that formerly-obese women may have lower rates of fat oxidation than matched controls (Ranneries *et al.* 1998). The incidence of obesity in the UK is greater in women (particularly older middle-aged women) than in men (Prescott-Clarke & Primatesta, 1997). This difference may well involve difficulties associated with food choice and the control of energy intake.

High-fat foods have the potential to generate a high energy intake by means of a process referred to as 'passive overconsumption' (Lawton *et al.* 1993). This non-deliberate consumption of energy derived from fat can lead to excessive intakes of fat in a single eating episode (meal or snack), and can produce a marked short-term (Lawton *et al.* 1993) positive energy balance. High-fat foods consumed at a meal have been shown to increase meal size in lean healthy males (Cotton *et al.* 1994; Green *et al.* 1994; King & Blundell, 1995) and females (Green & Blundell, 1996*a*), and obese women (Lawton *et al.* 1993). A subsequent compensatory underconsumption following a high-fat meal has been shown in some studies (Foltin *et al.* 1990), but not others (Stubbs *et al.* 1993).

The action of high-fat foods on appetite is almost certainly due to a combination of the high palatability (Warwick & Schiffman, 1992) and energy density (Stubbs *et al.* 1996) of high-fat foods. These effects compromise appetite control through a weak action on satiation (Blundell *et al.* 1993). The effect of high-fat foods on subsequent satiety (inter-meal satiety) also appears weaker than that of high-carbohydrate (CHO) foods, probably due to differences in post-ingestive processing. Indeed, it has

Abbreviations: CHO, carbohydrate; VAS, visual analogue scales.
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been asserted that, 'joule-for-joule', fat may exert a weaker effect on satiety than carbohydrate (Rolls *et al.* 1994).

Many snack foods are characterised by a high content of both fat and sugar (Drewnowski, 1990). There is some evidence that obese female participants rate sweet high-fat foods as preferred food items (Drewnowski *et al.* 1992). In addition, analysing the data presented in the *Dietary and Nutritional Survey of British Adults* (Gregory *et al.* 1990) has shown that there is a marked consumption of sweet high-fat foods among obese (BMI > 30 kg/m^2) women but not men (Macdiarmid *et al.* 1998). Sweet high-fat snacks have been shown to lead to overconsumption when compared with other sensory–nutrient combinations in lean males (Green & Blundell, 1996*b*). The effects of experimental manipulations of sweet high-fat or high-CHO foods on meal size has not been examined in the obese.

Lawton *et al.* (1993) showed that the energy intake of obese women at a test meal was increased when high-fat foods were consumed. Analysis of subsequent energy intake measured using food diaries suggested that energy intake was not reduced following the high-fat foods relative to the high-CHO foods. Conversely, some evidence suggests that obese individuals may compensate for a reduction in energy intake produced by a reduction in fat content of a meal (Fricker *et al.* 1995).

The present study included a manipulation of both meals and snacks because of opinions concerning the role of these different eating episodes in leading to a positive energy balance and weight gain. Although it is frequently claimed that snacking leads to weight gain, there is little objective evidence to support this claim (Mela & Rogers, 1993; Green & Burley, 1995). This study provided an opportunity to gather some evidence by comparing the impact of nutrient manipulations at a meal or snack on total test-day intake. Lawton *et al.* (1998) have shown that high-fat snack interventions do not lead to significantly increased daily energy intake but do markedly increase daily fat intake.

The present study examined the effect of highly-palatable high-fat and high-CHO foods, within the context of a normal meal pattern, on energy intake and motivation to eat of obese females. The effect of *ad libitum* consumption of (1) high-fat and high-CHO foods at a lunch test meal on lunch and subsequent dinner meal size, and (2) sweet high-fat and high-CHO snack foods at a snack test meal on snack and subsequent dinner meal size were examined. The effects of consumption of high-fat and high-CHO foods at a lunch and snack on motivation to eat and total test-day energy and macronutrient intakes were also examined. The study provided an opportunity to examine issues concerning food and eating episodes in obese women, and to comment on other issues of theoretical importance.

Methods

Study design

The study used a within-subject design. Four nutritional challenges were introduced over a period of 4 weeks. The nutritional challenges involved *ad libitum* consumption of a high-fat and high-CHO lunch, and a high-fat or high-CHO snack. The challenges were presented in four different orders to counterbalance the order-of-treatment effect: high-fat lunch, high-fat snack, high-CHO lunch, high-CHO snack (participants nos.1, 5, 9, 13); high-CHO lunch, high-CHO snack, high-fat lunch, high-fat snack (participants nos. 2, 6, 10, 14); high-fat lunch, high-CHO snack, high-CHO lunch, high-fat snack (participants nos. 3, 7, 11, 15); high-CHO lunch, high-fat snack, high-fat lunch, high-CHO snack (participants nos. 4, 8, 12).

Participants

Fifteen healthy obese women were recruited from the outpatient Obesity Clinic of the local general hospital. Patients with stable weight (± 2·5 kg) during the 2 months before the start of the study were included.

The fifteen participants were aged 21–56 (mean 37, (SD 9)) years. Their mean weight at the beginning of the study was 104·3 (SD 14·8) kg and their mean BMI was 39·2 (SD 3·5) kg/m^2. The thirteen participants who completed the study satisfactorily were aged 25–56 (mean 38 (SD 8)) years. Their mean pre-study weight was 104·2 (SD 15·0) kg and their mean BMI was 39·2 (SD 3·8) kg/m^2. The data obtained from two participants (nos. 6 and 9) were excluded from the analyses as they either failed to return the food box or consumed a meal not obtained from the food box on one of the test days.

Participants had no special dietary instruction for the duration of the study and were asked to maintain their normal dietary habits. Participants were not given any physical activity instruction but were simply asked to maintain their normal level of exercise throughout the study. Participants were requested not to drink alcohol to excess the day before each experimental day and on each experimental day.

Test day procedure

Participants were instructed to consume their customary breakfast on each test day, and to consume the same breakfast at the same time on each test day. Participants were asked not to eat or drink following breakfast, although they were permitted to consume one cup of tea or coffee during the course of the morning if this was their usual habit. One cup of tea or coffee was offered on the first test day with each test meal and, if taken, was given and consumed on subsequent test days as on the first test day. Caffeine intake was therefore kept constant. Unlimited drinking water was permitted throughout the experimental day and offered at each test meal. Participants were requested to arrive at the Unit 15 min before their test lunch.

Participants consumed all meals alone in a quiet small room cubicle. All cubicles were similar in appearance and size. Participants were requested not to read whilst consuming a meal.

Ad libitum *lunch test days*. Participants were presented with a lunch test meal which consisted of a range of high-fat or high-CHO foods at 12.00 hours (in some cases lunch was given later to suit the participants' timetable, although, the time interval between meals remained constant). Participants were requested to eat from the foods until they felt comfortably full. The sensory quality of the meal was then rated. Participants were then requested to refrain from eating and drinking (except water) until their next test meal (dinner) 4 h later (one cup of tea or coffee during the afternoon was permitted if this was their normal habit). Participants were requested to consume exactly the same drink on each of the test days. Participants either remained in the Unit or left and returned in time for the next test meal. A further *ad libitum* test meal (dinner) was presented 4 h after the lunch test meal. This meal consisted of a range of foods of medium palatability. Participants were requested to eat from these foods until they felt comfortably full, and to complete sensory ratings following the meal. Following this meal participants left the unit with a food box to eat from for the rest of the evening, and a record sheet to record what and when they ate from the box. Participants completed visual analogue scales (VAS) to measure motivation to eat at regular intervals throughout the experimental day.

Ad libitum *snack test days*. Participants were presented with a fixed-energy lunch meal of medium palatability at 12.00 hours (in some cases lunch was given later to suit the participants' timetable, although the time interval between meals remained constant). Participants were requested to consume all the meal, and to complete sensory ratings. Participants were then requested to refrain from eating and drinking (except water) until the test snack 2 h later. An *ad libitum* selection of snacks were presented 2 h following the lunch meal. These snacks consisted of a range of sweet foods high in CHO or high in fat. Participants were requested to eat from these foods until they felt comfortably full, and to complete sensory ratings as before. A further *ad libitum* test meal (dinner) was presented 2 h following the test snack. The test-meal dinner and procedure following the test dinner were the same as on the days when the test lunches were consumed.

Test meals

All foods presented were those encountered in real eating situations. All were palatable, not unusual and were obtainable from the supermarket. The protein levels were kept low and constant between the nutritional challenges. Protein content of a meal has been shown to increase satiety (Barkeling *et al.* 1990). Dietary fibre has been shown to influence appetite (Blundell & Burley, 1987). Most of the foods selected for the test snack and lunch were considered to contain only small amounts of dietary fibre. Where foods were considered higher in fibre (coleslaw, popcorn), they were offered in both the high-fat and high-CHO conditions. The glycaemic index of the foods was not considered; foods were selected only to meet specific criteria concerning macronutrient content. Foods were given at customary meal times. This procedure allowed experimental manipulations within the context of natural meal patterns.

Palatability is thought to be the most consistent variable influencing the amount eaten (Spitzer & Rodin, 1981). The palatability of the ranges of foods used in the selections was therefore controlled. Before the start of the study each participant completed a preference form to ensure that the foods were acceptable. Acceptability was assessed by using a 9-point scale, with 9 being rated as 'like extremely'. If participants rated items ≥ 5, it was concluded that they did not dislike the food. If a food item was rated <5, then a 'liked' food item was substituted. Any substituted foods were similar in texture and nutritional content. All food items were therefore rated as ≥ 5, except for salad and condiments in the *ad libitum* test dinner.

Ad libitum *test lunch*. Two types of test lunch were used: high-fat low-CHO, and high-CHO low-fat, classified according to the percentage of energy obtained from fat and CHO. Each *ad libitum* lunch consisted of seven food items. The seven high-fat food items in the high-fat lunch derived more than 51 % total energy from fat and less than 42 % from CHO. Six of the high-CHO food items in the high-CHO lunch derived more than 54 % total energy from CHO and less than 30 % from fat. One food item (coleslaw) derived 48 % energy from fat and 41 % energy from CHO. However, as the fat content was 3·2 g/100 g coleslaw, this item was considered to be a low-fat food. Table 1 lists the food items, nutritional information and quantity offered. An excess of food was offered, and no participant ate all the foods on any one occasion.

Fixed test lunch. This meal was of medium palatability, consisting of hot meat-and-potato pie, green peas, two sweet biscuits and a glass of orange juice. The energy content of the meal was 2·08 MJ (497 kcals); 16 % energy from protein, 51 % energy from CHO and 33 % energy from fat. Participants were requested to consume all the meal. Lasagne was offered as an alternative if participants expressed a dislike for meat-and-potato pie before the start of the study, and alternative vegetables were offered if green peas were disliked. The macronutrient and energy contents of the substituted foods were very similar to the foods they replaced.

Ad libitum *test snack*. The *ad libitum* sweet snacks used were high-fat low-CHO and high-CHO low-fat, classified according to the percentage of energy obtained from fat and CHO. Each snack consisted of five food items. The five high-fat food items in the high-fat snack derived >52 % total energy from fat and <41 % energy from CHO. The five high-CHO food items in the high-CHO snack derived >60 % of total energy from CHO and <33 % from fat. Table 2 lists the food items, nutritional information and quantity offered. An excess of food was offered, and no participant ate all the foods on any one occasion. The dessert was served chilled, and the items were presented on one tray.

Ad libitum *test dinner*. At the *ad libitum* evening meal participants were provided with a range of foods of medium palatability from which they could select the type and amount they wished to consume. The foods offered are often consumed as part of a meal and included bread, margarine, sliced cold meat, cheese, salad items, condiments, potato crisps, fruit yoghurt and fruit.

Food for the rest of the day. Participants were provided with a range of food items commonly consumed as a snack in the evening, including bread, margarine, jam, cheese, milk-based pudding (e.g. fruit yoghurt or chocolate dessert), chocolate biscuits and potato crisps. The food items did not require refrigeration and were presented in a sealed plastic box. An excess of food was offered, and no

Table 1. Quantity, energy content and macronutrient composition of food items offered in the high-carbohydrate (CHO), low-fat and high-fat low-CHO *ad libitum* test lunches

		Energy		Protein		CHO		Fat	
	Quantity (g)	MJ/100 g	kcal/100 g	g/100 g	% energy	g/100 g	% energy	g/100 g	% energy
High-CHO lunch									
1. Tuna mayonnaise sandwiches	Eight quarters	0·71	170	10·6	25	24·9	55	3·8	20
2. Coleslaw	200	0·25	60	1·8	12	6·5	41	3·2	48
3. Breadsticks	65	1·60	383	12·0	13	72·0	70	7·2	17
4. Crispy potato snacks (French Fries)	36	1·73	415	5·4	5	72·9	66	13·3	29
5. Ham and mushroom pizza	330	0·89	212	9·6	18	32·4	57	5·8	25
Or cheese and tomato pizza	330	0·94	225	8·9	16	33·0	55	7·3	29
6. Jelly confectionery	175	1·32	315	5·2	7	78·4	93	0·0	0
7. Low-fat strawberry yoghurt	300	0·36	87	4·7	22	14·2	61	1·7	18
High-fat lunch									
1. Tuna mayonnaise sandwiches	Eight quarters	1·18	282	11·1	16	16·4	22	19·6	63
2. Coleslaw	200	1·38	331	1·1	1	4·2	5	34·5	94
3. Maize snacks (cheese puffs)	50	2·22	531	9·1	7	50·9	36	33·7	57
4. Crackers with cheese filling (Ritz)	90	2·07	496	11·6	9	50·5	38	28·9	52
5. Meat-filled pastry (sausage rolls)	160	1·35	323	7·5	9	24·5	28	22·4	62
Or cheese and onion flan	365	1·12	267	8·8	13	22·1	31	16·5	56
6. Vanilla-flavour biscuits (Vienna)	Eight biscuits	2·29	548	4·4	3	60·0	41	33·9	56
7. Strawberry cream and yoghurt dessert	300	0·71	169	2·5	6	16·5	37	10·8	58

Table 2. Quantity, energy and macronutrient composition of food items offered in the sweet high-carbohydrate (CHO) and sweet high-fat *ad libitum* test snack meals*

		Energy		Protein		CHO		Fat	
	Quantity (g)	MJ/100 g	kcal/100 g	g/100 g	% energy	g/100 g	% energy	g/100 g	% energy
Sweet high-CHO snack									
1. Banana flavoured milk-based dessert	300	0·41	98	2·8	11	15·9	61	3·0	28
2. Fruit-preserve-filled sponge cake (Swiss roll)	170	1·18	283	4·9	7	66·2	88	1·7	5
3. Chocolate-and orange-topped biscuits	Eight biscuits	1·52	364	4·4	5	72·8	75	8·1	20
4. Toffee popcorn	75	1·64	393	2·6	3	83·1	79	7·9	18
5. White-chocolate cereal bars	Four bars	1·67	400	6·5	7	66·0	62	14·0	32
Sweet high-fat snack									
1. Gooseberry cream and yoghurt dessert	300	0·66	159	2·3	6	13·3	31	11·1	63
2. Roasted-nut cereal bars	Four bars	2·10	503	10·0	8	52·8	39	29·4	53
3. Croissants with fruit preserve and butter	Three croissants	1·73	414	5·9	6	42·9	39	25·5	55
4. Caramel popcorn	100	2·22	531	2·6	2	54·2	38	35·3	60
5. Chocolate-coated chocolate sponge cake	Three cakes	2·01	480	5·5	5	51·7	40	29·4	55

* Acceptability of individual food items was assessed before the start of the study. Substitute food items of similar texture and nutritional content were offered when necessary. Substitute food items for the sweet high-CHO snack test meal were chocolate-flavoured milk-based dessert (one participant) and chocolate sponge and fondant cakes (six participants). Substitute food items for the sweet high-fat snack test meal were chocolate dessert (one participant) and vanilla-flavoured biscuits (two participants).

participant ate all the foods on any occasion. Intake of beverages was not restricted and participants were asked to record in detail drinks consumed.

Motivational ratings

Participants were requested to complete VAS to measure subjective hunger and other sensations associated with the willingness to eat. The VAS were 100 mm lines anchored by descriptors at each end. Participants were asked to mark, with a single vertical line, at a point where the length of the line matched the subjective sensation. VAS were completed immediately before and after each meal, and half-hourly between the test lunch and test dinner.

VAS were also completed after each test meal to assess the sensory qualities of the foods following consumption. Participants were asked how tasty, salty, filling, pleasant, bland and satisfying they found the meal or snack using a 100 mm linear VAS. In addition, participants were asked to rate how sweet they found the snacks.

Statistical analysis

Energy and macronutrient content of the test meals and food diaries was measured using manufacturers' data and a computerised nutritional database (Comp-eat, version 4; Nutrition Systems, London, UK) based on the UK food composition tables (Holland *et al.* 1991). Portion sizes for estimation of intake from the food diaries were calculated using standard food portion sizes (Ministry of Agriculture, Fisheries and Food, 1993). The energy conversion factors used were 15·7 kJ/g (3·75 kcal/g) for CHO, 37·7 kJ/g (9 kcal/g) for fat and 16·7 kJ/g (4 kcal/g) for protein.

ANOVA was used to analyse the VAS post high-CHO or high-fat manipulation with time of rating and lunch or snack type as within-subjects variables. Student's paired t tests were used to analyse the differences in energy and macronutrient intakes between the challenges, and the sensory ratings of the test meals.

Total test-day energy and macronutrient intakes were calculated as the sum of all food and drink consumed throughout the day; the fixed breakfast, beverages, lunch meal, snack meal (when consumed), dinner meal and snack box intake. As two participants failed to return a record of intake from the evening snack box on one test day, analyses included data for thirteen participants.

Two participants consumed alcoholic drinks during the evening. One participant consumed no more than two units of alcohol (wine and spirits) on each test day except one. The other participant consumed 23 g whisky and 1759 g and 251 g lager on three test days respectively. The data were analysed excluding these two participants but no differences were seen in the probability levels for the snack box energy intake following the high-fat and high-CHO lunches (t 0·98, df 10, NS) and snacks (t −0·18, df 10, NS), or for the energy intake over the total test day following the high-fat and high-CHO lunch (t −3·22, df 10, $P < 0·01$) and snack (t −1·16, df 10, NS) challenges. Thus, rest of day and total test day intakes include energy and macronutrients obtained from alcoholic drinks.

The statistical software packages used were Statistical Analysis Systems version 6.10 (SAS Institute, Cary, NC, USA), Statistical Package for Social Scientists version 6.1 (SPSS Inc., Chicago, IL, USA) and Minitab version 5 (Minitab Inc., State College, PA, USA).

The data from participants nos. 6 and 9 were not included in the analyses. Thus, four participants were allocated to the high-fat lunch, high-CHO snack, high-CHO lunch, high-fat snack order of treatment and three participants to the other orders of treatment. No significant differences were seen between the energy intakes of the first and second lunch (t −0·32, df 12, NS) and snack (t 0·21, df 12, NS) presented.

Ethical considerations

The study was approved by the Research Ethics Committee of the local NHS Trust, as part of a wider study. Information about the study was provided and informed consent obtained from all participants. The participants were not informed as to the exact nature of the dietary manipulation, but were fully informed when they had completed the study.

Results

Lunch test days

Energy and macronutrient intakes. Energy and macronutrient intakes for the *ad libitum* test lunch, *ad libitum* test diner, rest of the day (snack box) and total test day are shown in Table 3. Energy intake was greater when the high-fat lunch was consumed than when the high-CHO lunch was consumed (t −5·93, df 12, $P < 0·001$). Energy intakes following the high-fat and high-CHO lunches did not differ at the test dinner (t 0·29, df 12, NS) or from the snack box (t 0·46, df 12, NS). Total day energy intake was less following the high-CHO lunch than following the high-fat lunch (t −3·76, df 12, $P < 0·01$).

Considering macronutrient intake, there was no significant difference between the protein intake at the high-CHO lunch and the high-fat lunch (t 1·17, df 12, NS).

CHO intake was 26 % total energy (72 g) at the high-fat lunch and 60 % total energy (101 g) at the high-CHO lunch. CHO intake (g) was significantly higher at the high-CHO lunch than at the high-fat lunch (t 3·66, df 12, $P < 0·01$), as would be expected. Total test day CHO intake (g) was higher when the high-CHO lunch was consumed (t 2·38, df 12, $P < 0·05$). The percentage energy obtained from CHO on the test day when the high-CHO lunch was consumed was 47 % compared with 35 % when the high-fat lunch was consumed.

Fat intake was 64 % total energy at the high-fat lunch (75 g) and 22 % total energy (16 g) at the high-CHO lunch. Fat intake (g) was significantly lower at the high-CHO lunch than at the high-fat lunch (t −11·14, df 12, $P < 0·001$), as would be expected. Further, total test day fat intake (g) was lower with the high-CHO lunch than the high-fat lunch (t −8·06, df 12, $P < 0·001$). The percentage energy obtained from fat on the test day when the high-CHO lunch was consumed was 35 % compared with 51 % when the high-fat lunch was consumed.

There was a large difference between mean weight consumed at the high-fat (337 (SD 75) g) and the high-CHO meal (397 (SD 68) g). Intake (g) was approximately 20 % greater with the high-CHO lunch than with the high-fat lunch (t 3·84, df 12, $P < 0·01$).

Sensory ratings. There were no significant differences in the recorded palatability of the high-fat and high-CHO lunches on the descriptors of tasty (t 1·07, df 12, NS), salty (t 1·33, df 12, NS), filling (t 1·85, df 12, NS), pleasant (t 1·08, df 12, NS), bland (t −0·30, df 12, NS) and satisfying (t 0·18, df 12, NS). The lunch meals were rated as highly palatable by the participants. The mean rating on the 100 mm scale for the descriptor tasty was 78 (SD 11) mm for the high-CHO lunch and 70 (SD 28) mm for the high-fat lunch. The mean rating on the 100 mm scale for the descriptor pleasant was 79 (SD 18) mm for the high-CHO lunch and 71 (SD 24) mm for the high-fat lunch.

Motivation to eat. Fig. 1 shows the temporal profile of hunger ratings from immediately before the start of the lunch (pre-lunch) to immediately following the test dinner. Hunger levels can be seen to fall after meals and then rise until the next meal. Hunger levels following the two lunch types appear very similar. Two-way repeated measures ANOVA of hunger ratings from post-lunch to pre-dinner

Table 3. Dietary energy and macronutrient intakes of thirteen obese women at a high-carbohydrate (CHO) *ad libitum* test lunch, a high-fat *ad libitum* test lunch, a subsequent *ad libitum* test dinner, over the rest of the day and for the total test day*

(Mean values and standard deviations)

	High-CHO-lunch test day		High-fat-lunch test day		Statistical significance of difference between challenges	
	Mean	SD	Mean	SD	*t* (df 12)	*P*<
Ad libitum test lunch						
Energy: MJ	2·63	0·70	4·39	1·25	−5·93	0·001
kcal	628	167	1051	298		
Fat (g)	15·6	3·8	75·2	20·8	−11·14	0·001
CHO (g)	101·0	32·3	72·4	31·0	3·66	0·01
Protein (g)	27·2	6·1	25·5	6·2	1·17	NS
Ad libitum test dinner						
Energy: MJ	2·49	0·99	2·43	1·05	0·29	NS
kcal	595	237	582	251		
Fat (g)	30·4	13·7	27·7	14·6	1·04	NS
CHO (g)	53·6	26·1	58·3	26·5	−0·96	NS
Protein (g)	29·9	10·3	28·4	11·5	1·00	NS
Rest of day†						
Energy: MJ	1·70	127	1·56	1·23	0·46	NS
kcal	406	305	374	295		
Fat (g)	18·8	14·4	15·5	13·9	0·80	NS
CHO (g)	45·6	37·0	45·9	36·1	−0·03	NS
Protein (g)	12·3	12·2	10·8	9·2	0·67	NS
Total test day‡						
Energy: MJ	7·67	2·27	9·16	2·76	−3·76	0·01
kcal	1835	543	2192	661		
Fat (g)	72·3	23·7	124·3	37·0	−8·06	0·001
CHO (g)	230·3	78·7	205·3	84·6	2·38	0·05
Protein (g)	75·8	18·0	71·0	19·1	1·92	NS

* For details of subjects, procedures and test lunches, see pp. 522–525 and Table 1 respectively.
† Calculated from food items consumed from the snack box plus beverages consumed in the evening.
‡ Calculated from the fixed breakfast, *ad libitum* test lunch, *ad libitum* test dinner, snack box and beverages consumed throughout the day.

showed a main effect of time (F(5,60) 15·95, $P < 0·001$), but no main effect of lunch type (F(1,12) 0·08, NS) or lunch × time interaction effect (F(5,60) 1·42, NS).

Snack test days

Energy and macronutrient intakes. The energy intake from the snack can be seen in Table 4. Energy intake was higher with the high-fat snack than with the high-CHO snack (t −3·93, df 12, $P < 0·01$).

Energy intakes for the test dinner, the rest of the day (snack box and beverages) and the total test day are shown in Table 4. There were no significant differences between the energy intakes of the test dinner (t 0·71, df 12, NS) or the rest of the day (t −0·42, df 12, NS). Examination of Table 4 shows that energy intake over the total test day was higher when the high-fat snacks were consumed. However, there were no significant differences between the two challenges (t −1·70, df 12, NS).

Mean intakes of protein were 8 (SD 4) g and 10 (SD 4) g for the high-CHO and high-fat snacks respectively; this difference was significant (t −2·32, df 12, $P < 0·05$). Protein intakes from the snacks were, however, similar in terms of percentage energy intake: 7 high-CHO snack, and 6 high-fat snack. The increase in protein intake with the high-fat snack, therefore, appeared to reflect the increased energy intake.

As expected, fat intake (g) at the test snack was significantly higher with the high-fat snack (42 g) than with the high-CHO snack (11 g; t −6·40, df 12, $P < 0·001$). CHO intake (g), however, was not significantly different between the two challenges for either the test snack (t 1·65, df 12, NS) or total test day (t 1·06, df 12, NS). Total test day fat intake (g) was lower with the high-CHO snack than with high-fat snack (t −4·06, df 12, $P < 0·01$). The percentage energy obtained from fat for the total test day when the high-CHO snack was consumed was 35 % compared with 44 % when the high-fat snack was consumed.

Intake (g) of the high-CHO snack was 191 (SD 127) g and of the high-fat snack was 167 (SD 90) g, but this difference was not significant (t 0·78, df 12, NS).

Sensory ratings. There were no significant differences in the recorded palatability of the high-fat and high-CHO snacks on the descriptors of taste (t 0·35, df 12, NS), salty (t −1·10, df 12, NS), filling (t 0·17, df 12, NS), pleasant (t −0·57, df 12, NS), bland (t 1·09, df 12, NS), sweet (t 1·21, df 12, NS) and satisfying (t −0·37, df 12, NS). The snack meals were rated as highly palatable by the participants. The mean rating on the 100 mm scale for the descriptor tasty was 84 (SD 13) mm for the high-CHO snack and 82 (SD 13) mm for the high-fat snack. The mean raging on the 100 mm scale for the descriptor pleasant was 85 (SD 16) mm for the high-CHO snack and 86 (SD 13) mm for the high-fat snack.

Motivation to eat. Fig. 2 shows the temporal profile of

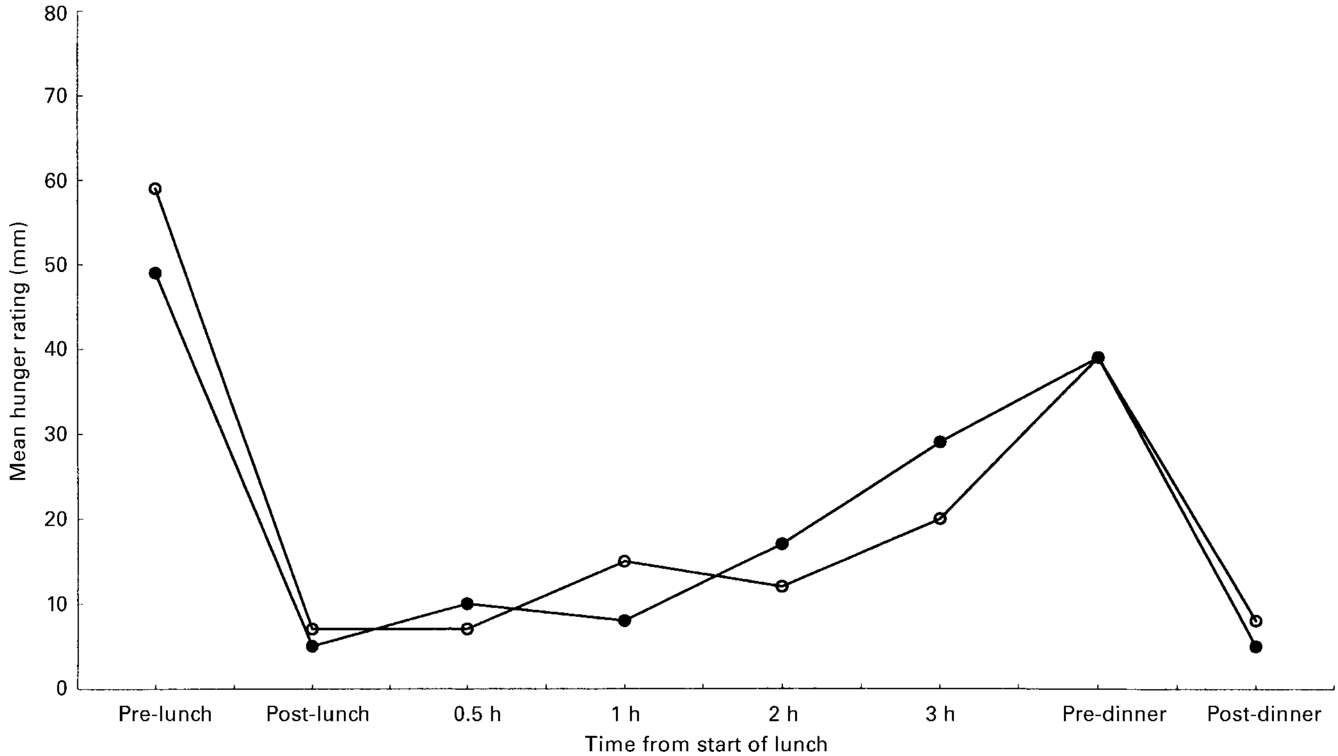

Fig. 1. Temporal profile of rated hunger immediately before (pre-lunch) until immediately following *ad libitum* consumption of a high-fat (●) or high-carbohydrate (○) test lunch in obese women. Subjective hunger ratings were measured on visual analogue scales with 100 mm lines anchored by descriptors at each end. For details of procedures and test lunches, see pp. 522–525 and Table 1.

Table 4. Dietary energy and macronutrient intakes of thirteen obese women at a high-carbohydrate (CHO) *ad libitum* test snack, a high-fat *ad libitum* test snack, a subsequent *ad libitum* test dinner, over the rest of the day and for the total test day*

(Mean values and standard deviations)

	High-CHO snack test day		High-fat snack test day		Statistical significance of difference between challenges	
	Mean	SD	Mean	SD	*t* (df 12)	*P*<
Ad libitum test snack						
Energy: MJ	1·91	1·05	2·89	1·39	−3·93	0·01
kcal	458	252	691	333		
Fat (g)	11·3	5·9	42·3	20·8	−6·40	0·001
CHO (g)	86·5	50·8	71·5	34·8	1·65	NS
Protein (g)	7·9	4·1	10·3	4·3	−2·32	0·05
Ad libitum test dinner						
Energy: MJ	2·19	0·72	2·03	0·74	0·71	NS
kcal	524	172	486	177		
Fat (g)	27·4	11·3	26·0	12·6	0·48	NS
CHO (g)	46·6	16·7	40·4	20·6	1·09	NS
Protein (g)	25·4	9·5	25·1	6·5	0·13	NS
Rest of day†						
Energy: MJ	1·50	0·83	1·64	1·26	−0·42	NS
kcal	358	199	393	302		
Fat (g)	17·0	9·0	18·5	14·4	−0·36	NS
CHO (g)	41·0	31·5	42·2	36·5	−0·11	NS
Protein (g)	8·0	5·8	12·2	11·2	−1·81	NS
Total test day‡						
Energy: MJ	8·49	2·24	9·47	2·69	−1·70	NS
kcal	2030	535	2266	643		
Fat (g)	79·2	22·9	110·3	35·2	−4·06	0·01
CHO (g)	274·2	88·3	255·6	83·7	1·06	NS
Protein (g)	66·9	16·5	73·4	16·9	−1·68	NS

* For details of subjects, procedures and test snacks, see pp. 522–525 and Table 2 respectively.
† Calculated from food items consumed from the snack box plus beverages consumed in the evening.
‡ Calculated from the fixed breakfast, fixed lunch, *ad libitum* snack, *ad libitum* test dinner, snack box and beverages consumed throughout the day.

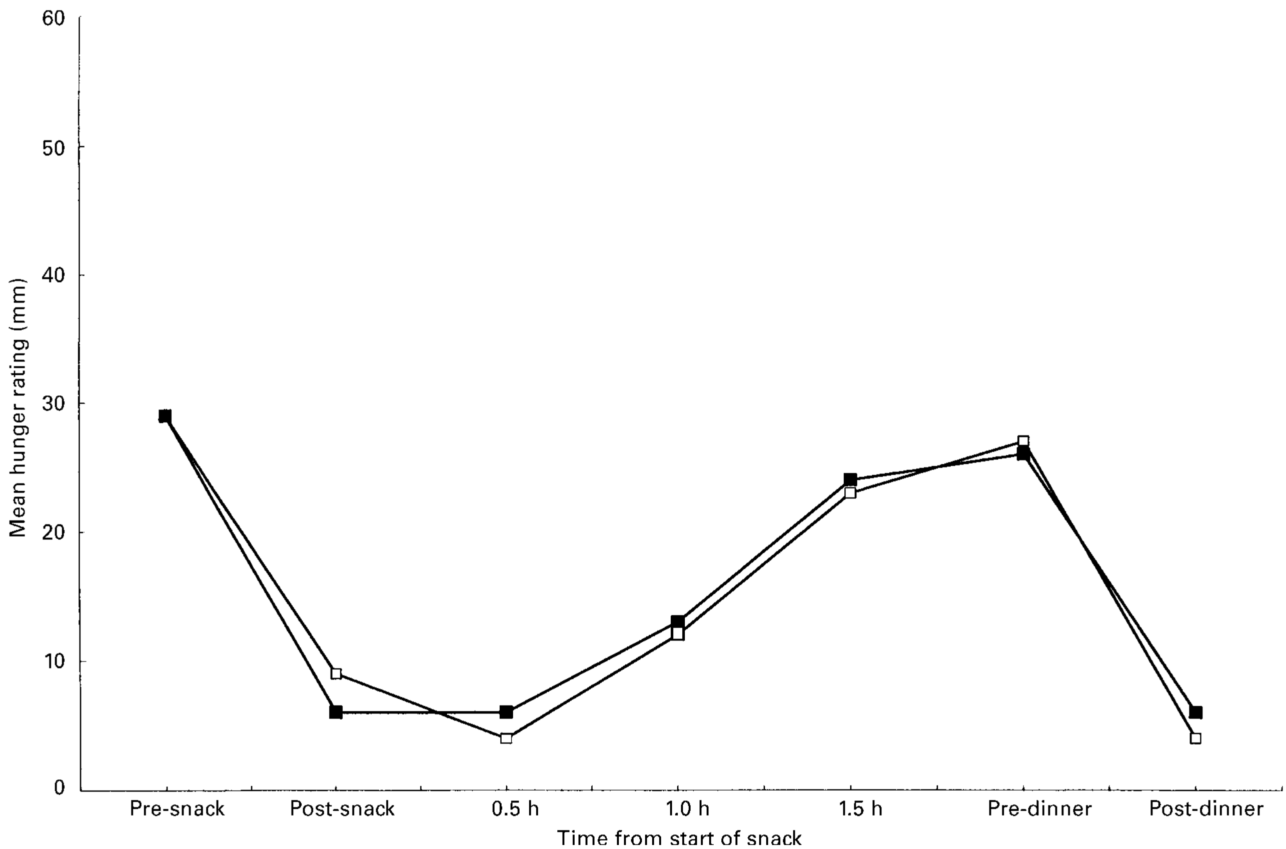

Fig. 2. Temporal profile of rated hunger immediately before (pre-snack) until immediately following *ad libitum* consumption of a high-fat (■) or high-carbohydrate (□) test snack in obese women. Subjective hunger ratings were measured on visual analogue scales with 100 mm lines anchored by descriptors at each end. For details of procedures and test snacks, see pp. 522–525 and Table 2.

hunger ratings from immediately before the start of the snack (pre-snack) to immediately following the test dinner. Hunger levels can be seen to fall after consumption of the snacks and then rise until the next meal. Hunger levels following the two snack types appear very similar. Two-way repeated measures ANOVA of hunger ratings from post-snack to pre-dinner showed a main effect of time [$F(4,48)$ 13·11, $P < 0{\cdot}001$], but no main effect of snack type [$F(1,12)$ 0·00, NS] or snack × time interaction effect [$F(4,48)$ 0·19, NS].

Discussion

Energy intake at a test meal was increased when high-fat foods were consumed freely relative to high-CHO foods. No intensification of satiety was observed with the high-fat foods as recorded hunger was similar following the high-fat and high-CHO test meals, even though they differed in energy value and weight. The palatability ratings of the high-fat and high-CHO test meals were similar. The high-fat test meals, therefore, appear to have had a weaker effect on both satiation (meal size) and satiety (post-meal hunger).

Overeating at a meal with high-fat foods relative to high-CHO foods has been demonstrated previously in normal-weight men (Green *et al.* 1994; King & Blundell, 1995) and obese women (Lawton *et al.* 1993), and appears to be a well-observed natural phenomenon (Blundell & Macdiarmid, 1997). The results of the present study are in agreement with previous findings. The high-fat foods were more energy dense than the high-CHO foods. Stubbs *et al.* (1996) have demonstrated that when isoenergetically-dense high-fat and high-CHO foods are consumed *ad libitum*, energy intake of high-fat and high-CHO foods are similar. It is likely, therefore, that the weak effect of high-fat foods on satiation is due to a high energy density. The consumption of high-fat foods at a test meal did not appear to increase satiety. Weight and volume are likely to influence satiation (Blundell & Stubbs, 1998), particularly in short-term studies such as the present study.

Once ingested, the pre- and post-absorptive physiological responses of fat and CHO differ and the extent to which this difference influences satiety differentially should be considered (Blundell & Stubbs, 1998). Blundell & Stubbs (1999) have questioned whether the effect of energy density can be considered independently from the nutrients which provide the energy.

A compensatory reduction for the higher energy intake at the high-fat meal or snack was not seen in the subsequent test meal (dinner). Consequently, energy over the total test day was increased when the high-fat lunch was consumed. There appeared to be a trend towards a higher daily energy intake when the high-fat snack was consumed, although energy intake was not significantly increased following the high-fat snack (Table 4). A lack of compensatory reduction in energy intake of a subsequent meal following overconsumption of a high-fat meal (relative to high-CHO meal) has been demonstrated in lean men (Cotton *et al.* 1994). Correspondingly, consumption of a palatable *ad libitum* high-fat meal has been shown to lead to a higher daily energy intake than consumption of an equally palatable high-CHO snack in lean men (Green *et al.* 1994) and women (Green & Blundell, 1996*a*). The present study demonstrates that obese women also show a similar response following overconsumption of high-fat foods at a meal. Energy intake at the subsequent meal was not reduced following a high-energy high-fat meal, resulting in an increase in overall daily energy intake. It is possible that a compensatory reduction in energy intake may have been delayed. Food intake may have been reduced in the days following the challenge to compensate for the increased intake with the high-fat foods. Other long-term studies on lean individuals, however, have suggested that energy compensation does not occur (Stubbs *et al.* 1995*a*,*b*).

An important consequence of the experimental food manipulations was the effect on mean daily fat intake, since high-fat diets have been associated with CHD, various types of cancer and hyperlipidaemia, and may lead to complications in obese women. *Ad libitum* consumption of high-fat foods at both a snack and lunch meal resulted in an increase in the percentage energy obtained from fat in the diet over the total test day. Consumption of the high-CHO foods at a meal resulted in a lower percentage energy obtained from fat.

The lunch and snack test meals generated similar effects on satiation and satiety. The snack size was smaller than the lunch. The mean hunger level of the participants at the start of the snack test meal was lower than that at the start of the lunch meal. Food intake, therefore, may have been in response to hunger, although participants may have restricted their intake of the snack test meal and not the lunch due to cognitive factors. Women may perceive sweet snacks as unhealthy (Grogan *et al.* 1997).

Sweet high-fat snacks have been shown to lead to overconsumption in comparison with sweet high-CHO snacks in lean males (Green & Blundell, 1996*b*). In the present study sweet high-fat snack food promoted overconsumption relative to sweet high-CHO snacks in obese females.

The participants' level of dietary restraint was not considered in the analyses of the study. It is unlikely that dietary restraint could explain the differences in consumption between the high-fat and the high-CHO foods. Only one participant was able to identify the food selections as being high-fat and high-CHO. The other participants reported that they were unaware of the macronutrient manipulations.

Previous studies on normal-weight individuals have shown that *ad libitum* consumption of high-fat foods results in increased energy intake but a reduction in the weight of food consumed (Blundell *et al.* 1995). However, it has been suggested that obese women eat the same weight of food whether it is high-fat or high-CHO (Lawton *et al.* 1993). The results of the present study indicate there was no significant effect of snack type on weight of the snack consumed. However, a greater weight of foods was consumed at the high-CHO test lunch than the high-fat test lunch. These experiments demonstrate that when presented with the opportunity to eat freely, individuals do not invariably eat a constant weight of food irrespective of the taste or composition. As in previous studies where foods varying in nutrient composition and energy density have been used, it is clear that palatability (Mela & Rogers, 1998) and macronutrient content (Blundell *et al.* 1995) influence the amount (weight) of food eaten. Neither obese nor lean individuals automatically consume the same amount when foods are discernibly different. In the present study the obese participants did not show an internally consistent pattern; they ate significantly different weights at the lunch, and different weights (but not significant) at the snack.

These results demonstrate that the macronutrient content of food consumed at both a snack meal and main meal can affect satiation and satiety in healthy obese females. This effect has been demonstrated in previous studies with healthy lean men (Cotton *et al.* 1994; Green *et al.* 1994; King & Blundell, 1995; Green & Blundell, 1996b) and women (Green & Blundell, 1996*a*) and one study with healthy obese women (Lawton *et al.* 1993). *Ad libitum* consumption of palatable high-fat foods relative to high-CHO foods increased energy intake of a meal without intensifying satiety. Whilst consumption of high-fat foods resulted in a significant increase in daily energy intake only when the foods were consumed at lunch, energy intake from fat over the test day increased from 35 % to >40 %, regardless of whether high-fat foods were consumed at a snack or lunch meal.

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